# ATMOSPHERIC WATER GENERATOR:

# To meet the drinking water requirements of a household in coastal regions of India

*A thesis submitted in partial fulfilment of the requirements for the degree of*

**Bachelor of Technology**

in

**Mechanical Engineering**

by


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# CERTIFICATE

This is to certify that the thesis entitled, "**Atmospheric Water Generator: to meet the drinking water requirements of a household in coastal regions of India**" submitted by **ABHISHEK DASH** and **ANSHUMAN MOHAPATRA** in partial fulfilment of the requirement for the award of Bachelor of Technology degree in Mechanical Engineering at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance. To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

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# Abstract

Water scarcity is one of the burning issues of today's world. Though water covers more than two third (about 70%) of the Earth's surface but still fresh water which can be used for drinking and carrying out everyday chores remains scarce (only about 2.5%). The acute problem of water shortage, is mainly faced by the countries with long coastlines and the island nations, which do not have adequate fresh water sources like rivers and ponds. As a result most of these countries meet their water demands by desalination of sea water which is a very costly affair. Also it may so happen that these desalination plants may fail which will cause acute water shortage. This is what just recently happened in Maldives. So there is an urgent need for countries like Maldives and others, who depend solely on desalination plants to meet their water requirements, to find alternative methods to generate water in order to meet their water security needs.

India also needs to work forward in this direction in order to address this issue. Even though it has a very large coastline but still people face water scarcity. Till now India has not devised any way by which water from sea can be used to provide drinking water to the people.

This project aims to solve this problem. In the coastal areas the relative humidity is quite high (around 70-80%). So, the air in coastal areas can be used to meet the water needs of people by using a dehumidifier unit. Further the solar insolation is quite high in these areas round the year. This can be used to provide necessary power to the dehumidifier unit. Thus drinking water can be obtained from the atmosphere by harnessing solar energy. Such a device is called Atmospheric Water Generator.

**Keywords:** Atmospheric Water Generator, Desalination, Relative humidity, Dehumidifier unit

# Table of contents

# List of figures

# List of tables

# *Chapter-1*

# Introduction

The aim of the project is to create a portable device that can be used to meet the water requirements of a regular household. The device will first condense water present in the atmosphere and then purify it so that it can be used for drinking.

While designing the atmospheric water generator it was identified that three requirements were necessary to ensure that the final project would effectively fulfil its intended purpose. They are-

- Potability of Water - Water produced by the design must conform to the World Health Organization (WHO) drinking water quality standards.
- Simplicity of Use - Design must be operable by persons of limited technical experience.
- Safety - Design must not pose a hazard to users at any point during its normal operation.

We developed several goals that the design should be able to meet. They are-

- Flexibility in Power Source - The design should be able to utilize a variety of power sources, including (but not limited to) solar, wind, and the traditional power grid. .
- Maximize Efficiency - The design should maximize the water produced per unit energy.
- Minimize Cost - The design should minimize the cost per unit water production for both capital cost and production cost.

## 1. Dehumidification techniques

When approaching the problem of atmospheric water generation the first step is to analyse different methods of dehumidification. In this application we seek to harness this water from the atmosphere and utilize it for drinking. Three common psychometric methods of dehumidification stood out during preliminary research; a temperature drop below the dew point (refrigeration condensing), pressure condensing, or a combination of the two. Along with this wet desiccation technique can also be used for the above purpose. Each of these techniques are discussed below:

### 1.1 Dehumidification by refrigeration

Traditional refrigeration cycle dehumidification remains the most prevalent method for generating water from atmospheric humidity. This method circulates air over cooling coils connected in a refrigeration cycle to bring the water in the air below its dew point. The dew point of the water is dependent on the vapour pressure and humidity and tends to be a relatively low temperature compared to the ambient conditions. To reach the dew point the air running through the unit will have to be cooled a considerable amount. This approach is expressed in Figure 1 below:

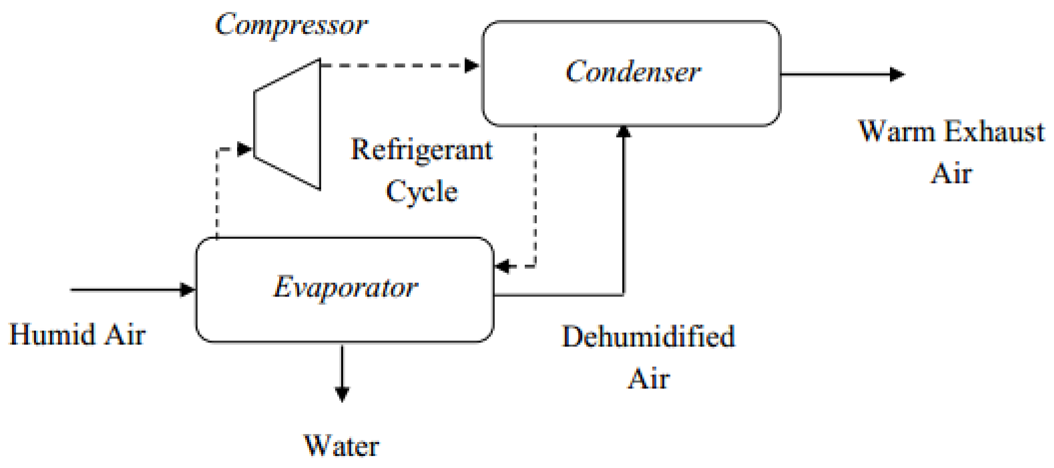



***Figure 1: Dehumidification by Refrigeration cycle***

Refrigeration can be achieved by many methods. Some of these are discussed below:

## A. Vapour Compression Method

Vapour-compression refrigeration is the most widely used method for air-conditioning in today's world.

The vapour-compression consists of a circulating liquid refrigerant as the medium which absorbs and removes heat from the space to be cooled and subsequently rejects that heat to the atmosphere. Figure 2 depicts a single-stage vapour-compression system. Basically the system has four components: a compressor, a condenser, a thermal expansion valve and an evaporator. Circulating refrigerant enters the compressor as saturated vapour and is compressed [1]. This results in high pressure which in turn is responsible for higher temperature. The compressed vapour then comes out as superheated vapour and attains a temperature and pressure at which condensation can take place with the help of cooling water or cooling air. That hot vapour is passed through a condenser where it is cooled and condensed. This is where the circulating refrigerant rejects heat from the system.

The condensed liquid refrigerant known as saturated liquid is next passed through an expansion valve where there is a sudden drop in pressure. This results in the adiabatic flash evaporation of the liquid refrigerant. The Joule-Thomson effect [2] as it is called lowers the temperature of the liquid and vapour refrigerant mixture which makes it colder than the temperature to be achieved (temperature of the enclosed space).

The cold mixture is passed through the coils in the evaporator. A fan circulates the warm air in the enclosed space across the coils carrying the cold refrigerant liquid and vapour mixture. That warm air evaporates the liquid part of the cold refrigerant and at the same time, the circulating air is cooled and as a result it lowers the temperature of the enclosed space to the temperature to be achieved. The circulating refrigerant absorbs and removes heat from the evaporator which is then rejected in the condenser and transferred by the water or air used in the condenser.

For the completion of the refrigeration cycle, the refrigerant vapour coming out of the evaporator which is again a saturated vapour is returned back into the compressor.

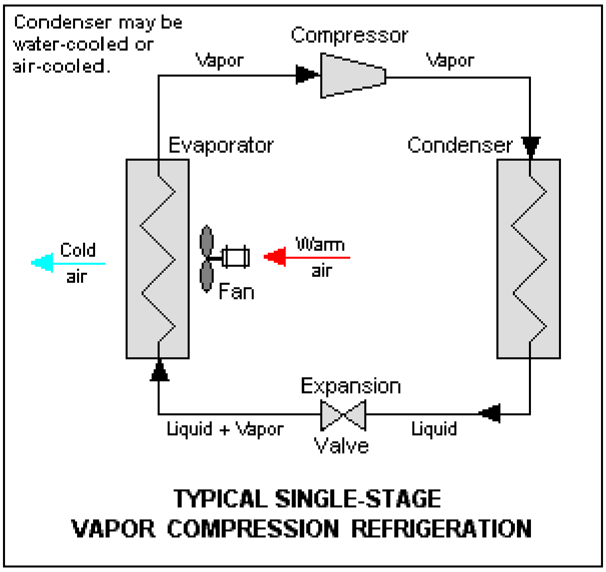



***Figure 2: Vapour Compression Refrigeration cycle***

1) <u>Thermodynamic analysis of the system</u>

The thermodynamics of the vapour compression cycle can be studied with the help of a temperature versus entropy diagram as shown in Figure 3. At point 1 as shown in the figure 3, the circulating refrigerant enters the compressor as a saturated vapour. From point 1 to point 2, there is compression of the circulating refrigerant at constant entropy and it comes out of the compressor as superheated vapour.

Between point 2 and point 3, the vapour travels through the condenser where there is removal of the superheat by cooling the vapour. From point 3 to point 4, the vapour travels through the rest of the condenser and thereby resulting in a saturated liquid. This process occurs at constant pressure.

From point 4 to 5, the saturated liquid refrigerant is routed through the expansion valve resulting in a sudden drop of pressure. That process is responsible for adiabatic flash evaporation and auto-refrigeration of a portion of the liquid which is known as Joule Thomson effect. The adiabatic flash evaporation process occurs at constant enthalpy.

From point 5 to 1, the cold refrigerant which is in a partially vaporised state is routed through the coils present in the evaporator which is responsible for its complete vaporisation by the warm air that is circulated by a fan present in the evaporator. The evaporator works at constant pressure (isobaric) and boils of all available liquid thereby superheating the liquid and vapour mixture of refrigerant. The resulting refrigerant vapour then flows back to the compressor inlet at point 1 thereby completing the thermodynamic cycle.

It should be noted that the above representation of the thermodynamic cycle does not take into account real world irreversibility like frictional pressure drop, slight internal irreversibility during the compression of the refrigerant vapour and non-ideal gas behaviour. Hence, the above idea simply represents an ideal vapour compression refrigeration cycle.

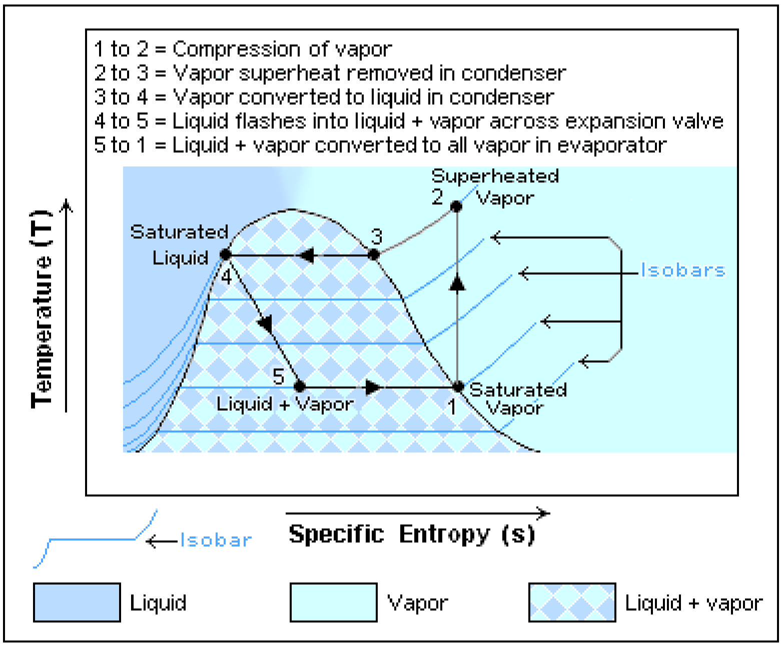



***Figure 3: T-S plot of vapour compression refrigeration cycle***

2) <u>Refrigerant</u>

After the introduction of the Montreal Protocol in the year 1987 all the parties agreed to phase out the dangerous ozone depleting refrigerants like CFCs which is one of the most crucial item of a vapour compression refrigeration system. Thus there is a gradual shift from the CFCs to the HCFCs with the motive of saving our ozone layer.

Now a days a lot of research is being carried out to explore environment friendly refrigerants, supercritical carbon dioxide known as R-744 [3] being one of them, which have same efficiencies as compared to existing CFC and HFC based refrigerants, and have many orders of magnitude lower global warming potential.

3) <u>Types of gas compressors</u>

The various types of compressors used are reciprocating, rotary screw, centrifugal, and scroll compressors. Each of these types have their respective application based on their size, noise, and efficiency and pressure ratings. Generally compressors are of three types. They are - open, hermetic, or semi-hermetic, depending on the position of the compressor and/or motor in relation to the refrigerant being compressed. The following configurations maybe achieved:

- Hermetic motor + hermetic compressor
- Hermetic motor + semi-hermetic compressor
- Open motor (belt driven or close coupled) + hermetic compressor
- Open motor (belt driven or close coupled) + semi-hermetic compressor

In most of the hermetic, and semi-hermetic compressors, the compressor and motor driving the compressor are integrated. The refrigerant being compressed during operation itself cools the hermetic motor. The obvious disadvantage being the motor is integral with that of compressor and in case of any failure in the motor it cannot be removed and repaired. Further the burnt out windings may contaminate the whole refrigeration system requiring the system to be entirely pumped down and replacement of the refrigerant [4].

An open compressor consists of a motor drive which is placed outside of the refrigeration system, and an input shaft is used to provide drive to the compressor which are sealed with the help of gland seals. Generally the open compressor motors are air-cooled and can be fairly easily exchanged or repaired without degassing of the refrigeration system. The disadvantage of this type of compressor is loss of refrigerant due to failure of gland seals.

Easy cooling and simple design makes the open motor compressors more reliable in case of high pressure applications where compressed gas temperatures can be very high. However the use of liquid injection for additional cooling can generally overcome this issue in most hermetic motor compressors.

## B. Peltier cooling

This method is exactly same as that of Vapour Compression Refrigeration method but here we use a Peltier device to achieve the required dew point temperature. Peltier device is compact, has less moving parts, is energy efficient and has a very long life span which requires very less maintenance.

1) Principle of Peltier Device

Thermoelectric cooling uses the Peltier effect to create a heat flux between the junctions of two different types of materials. A Peltier cooler, heater, or thermoelectric heat pump is a solid-state active heat pump which transfers heat from one side of the device to the other, with consumption of electrical energy, depending on the direction of the current. Such an instrument is also called a Peltier device, Peltier heat pump, solid state refrigerator, or thermoelectric cooler (TEC) [5].

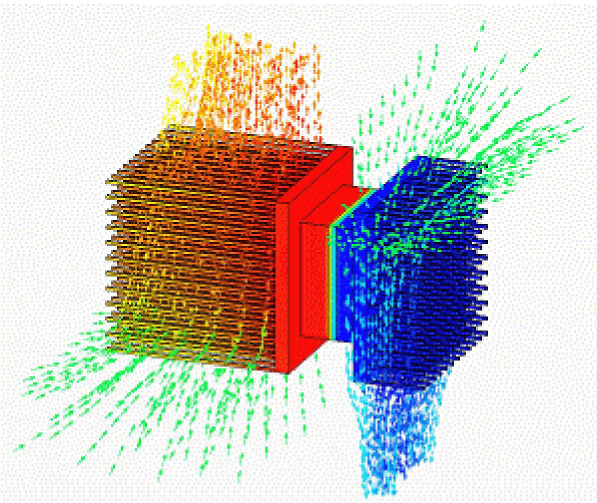


***Figure 4: Peltier device***

## 1.2 Dehumidification by compressing atmospheric air so as to increase its dew point temperature

It is possible to compress humid air so much that it will condense at the ambient temperature. As pressure increases the dew point rises; thus, enough compression will force the dew point above the ambient temperature resulting in spontaneous condensation; heat will transfer from the pressurized humid air to the ambient air. Compressing air to extract water could potentially require pressures up to five times the ambient pressure. This will require a very sturdy tank that can handle high amounts of stress in its walls. This method has great potential for low energy demands, especially if one was able to recapture some of the energy in the compressed air using a turbine or piston. The energy efficiency of this design option has great promise but it is heavily dependent on compressor and decompressor efficiency and humidity. Figure 5 below is a representation of this approach. The primary advantage of pressure dehumidification is the low energy requirement; the only unavoidable loss is the pressure applied to the water vapour. However, any inefficiency in the compression/decompression cycle is amplified by the large volume of air processed per unit water produced. Additionally, the rate of production when driven by natural convection cooling to the atmosphere is too slow for significant production; some mechanism to speed up this heat transfer needs to be implemented, increasing the energy cost. No existing atmospheric water generators utilize this approach.

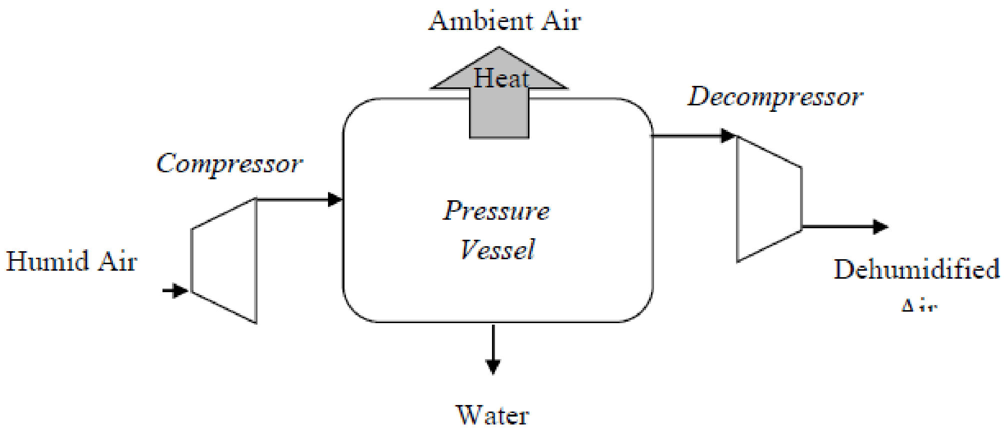



***Figure 5: Dehumidification by pressurisation***

## 1.3 Dehumidification by liquid desiccant method

A desiccant is a hygroscopic substance that induces or sustains a state of dryness (desiccation) in its vicinity. Commonly encountered pre-packaged desiccants are solids that absorb water.

Wet desiccation is a process where a brine solution is exposed to humid air in order to absorb water vapour from that air. The solution is then sent into a regenerator where the water vapour is extracted from the solution 2. This method has grown in popularity because of its efficiency and the ease with which it can be adapted to renewable energy, particularly solar. Figure 6 below is a basic representation of this approach.

A primary advantage to this approach is that the desiccant accomplishes the most difficult part of dehumidification, extracting the water from the air, without a direct expenditure of energy. The problem is thus recast into terms of regenerating the desiccant and capturing the resultant water. The main disadvantage of wet desiccation is the complexity that is introduced, both in terms of system and materials.

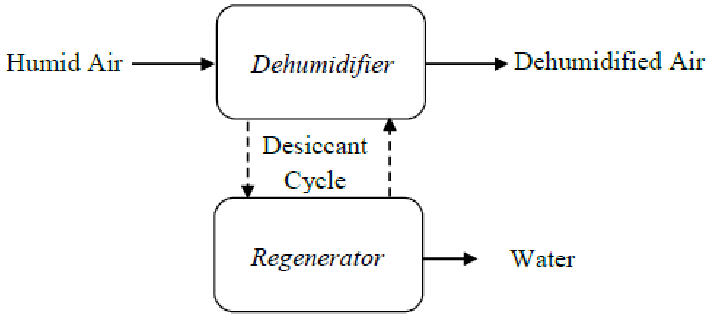



***Figure 6: Dehumidification by desiccation***

## 2. Filtration unit

The water obtained from the device after condensation is not fit for drinking. It contains a lot of germs and harmful bacteria which may cause diseases. Also it contains suspended particles which needs to be filtered out.

This can be achieved by first passing the condensed water through activated carbon filter. Then it is subjected to UV light so as to kill the harmful microbes.

# *Chapter-2*

# Literature review

Vapour compression refrigeration system, can be utilised to generate fresh drinking water by extracting water from humid ambient air by using Cooling Condensation process. In a cooling condensation based atmospheric water generator, a compressor circulates refrigerant through a condenser and an evaporator coil which cools the air surrounding it, lowering the air's temperature to that of dew point and causing water to condense. A controlled-speed fan pushes filtered air over the coil. The resulting water is then passed into a holding tank with purification and filtration system to keep the water pure. Atmospheric water generating technology offers 99.9% pure drinking water 365 days a year. The atmospheric water generator is an environmentally safe source of sustainable water.

The water generator, made from air-conditioning and dehumidifier parts, can generate enough amount of water to meet the drinking water requirements of a regular household. It also addresses the need for safe drinking water in remote areas and responds to the impending scarcity of potable water in certain areas due to the effects of global warming and natural disasters. It can also replace or supplement the currently available water devices in the market to reach the more remote areas (Anbarasu and Pavithra, 2011).

A senior design project was aimed at designing and creating a prototype of an atmospheric water generator (Niewenhuis et.al. 2012). They have tried to incorporate Liquid Desiccant method to extract humidity from air and convert it into drinking water. Wet desiccation is a process where a brine solution is exposed to humid air in order to absorb water vapour from that air. The solution is then sent into a regenerator where the water vapour is extracted from the solution. This method has grown in popularity because of its efficiency and the ease with which it can be adapted to renewable energy, particularly solar.

In their paper (Niewenhuis et.al. 2012) and others have also described a novel and unique method to extract water from air. They have said that it is possible to compress humid air so much that it will start condensing at the ambient temperature itself. As pressure increases the dew point rises; thus, enough compression will force the dew point above the ambient temperature resulting in spontaneous condensation.

But compressing air to extract water could potentially require pressures up to five times the ambient pressure. This will require a very sturdy tank that can handle high amounts of stress in its walls. This method has great potential for low energy demands, especially if one was able to recapture some of the energy in the compressed air using a turbine or piston. The energy efficiency of this design option has great promise but it is heavily dependent on compressor and decompressor efficiency and humidity. The primary advantage of pressure dehumidification is the low energy requirement; the only unavoidable loss is the pressure applied to the water vapour. However, any inefficiency in the compression/decompression cycle is amplified by the large volume of air processed per unit water produced. Additionally, the rate of production when driven by natural convection cooling to the atmosphere is too slow for significant production; some mechanism to speed up this heat transfer needs to be implemented, increasing the energy cost.

(Kabeela et.al. 2014) In his paper "*Solar-based atmospheric water generator utilisation of a fresh water recovery: A numerical study"* has done thermodynamic analysis for a Peltier device which is used to develop a device that uses the principle of latent heat to convert molecules of water vapour into water droplets called the Atmospheric Water Generator. It has been introduced a bit before, though it is not very common in India and some other countries. It has a great application standing on such age of technology where we all are running behind renewable sources. Here, the goal is to obtain that specific temperature, called the dew point temperature, practically or experimentally to condense water from atmospheric humid air with the help of thermoelectric Peltier (TEC) couple.

## 1. Critical observations from published papers

From the paper "*Vapour Compression Refrigeration System Generating Fresh Water from Humidity in the Air"* (Anbarasu and Pavithra 2011), we infer that even though dehumidifying unit using vapour compression refrigeration system is more effective than the Peltier system but it lacks in the sense that it is not portable and it generates a lot of sound. And also this system is more costly.

From the paper "*Water generator water from air using liquid desiccant method"* (Niewenhuis et.al., 2012), we observed that even though dehumidification by liquid desiccant method is new and possess a lot of potential theoretically but when the researchers made a prototype and tested it the results were not satisfactory. The device could produce only 72.1 mL of water per kW-hr.

After studying the paper "*Solar-based atmospheric water generator utilisation of a fresh water recovery: A numerical study"* (Kabeela et.al. 2014), we can in no way refuse to accept the fact that dehumidification unit using Peltier device is very portable and environment friendly. It has simple design and has high endurance capability. So, this type of Atmospheric Water Generator is the device which can be implemented in extreme situations like during floods or in desert and rural areas. It has great advantages as it works like a renewable source of atmosphere water and doesn't need a heavy power source. Applying this system in a highly humid region almost 1 Litre of condensed water can be produced per hour during the day light, which is a very promising result.

## 2. Objectives and scope of present work

- In fact there are many products that are available in the market which use this technology. But on prior research and going through the product development page of various companies we found that the devices which use this technology are very bulky and heavy. They are not portable and since they use a compressor they have heavy electricity demand and are not eco-friendly. Also these devices produce a lot of noise and require periodic maintenance. Since we wanted to make a portable device hence we thought of using some other method to achieve our goal.
- In their design report "*Water generator water from air using liquid desiccant method"* Niewenhuis and others have tried to incorporate liquid desiccant method for dehumidification. After they created a prototype and put it into testing they found that water output from the device was very dismal. Hence we decided not to use this method of dehumidification for our prototype.
- After going through all the available options we finally concluded that we would use a Peltier device to create the Atmospheric Water Generator. In the paper "*Solar-based atmospheric water generator utilisation of a fresh water recovery: A numerical study"* Kabeela and others had already done a numerical study of the efficacy of a Peltier device. We advanced the study by creating a CAD model first and then subjecting the CAD model to ANSYS (Fluent) analysis. Then we calculated for different environmental and humidity conditions, the dew point temperatures and then tallied it with the results obtained from ANSYS (Fluent) analysis. After getting the results we collected the metrological data for different coastal cities of India and analysed whether our designed prototype would function or not.
- Also for purification of condensed water we decided to use a commercially available filtration unit. This ensured that the water which is obtained from the device is potable and free from any bacteria and germs.

# *Chapter-3*

# CAD Model

Using CAD software a model was first created. The various components of the model are as follows:

1. **Fan assembly**

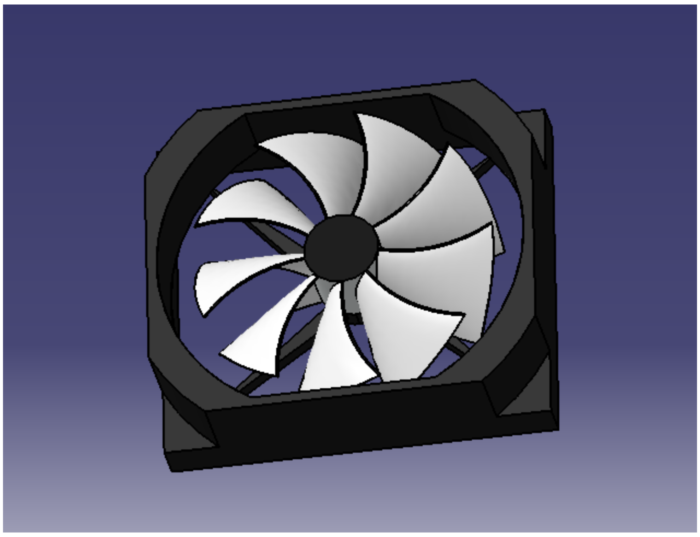


***Figure 7: Fan Assembly***

2. **Peltier assembly**

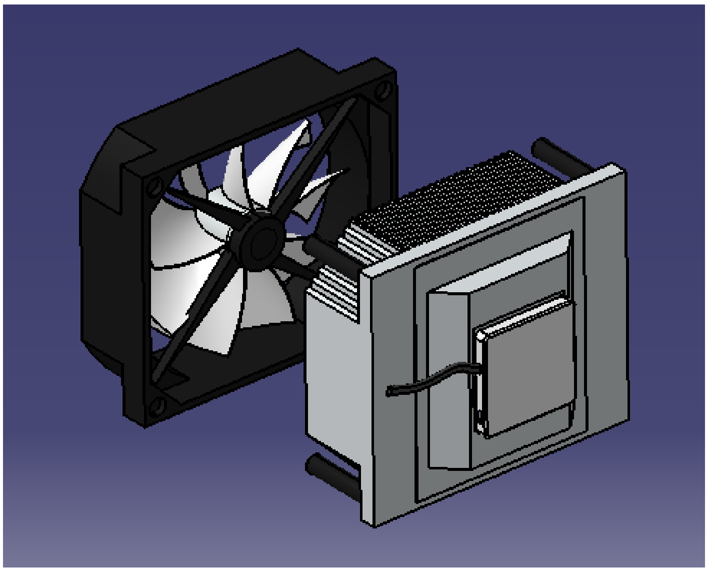


***Figure 8: Peltier with heat sink***

## 3. Casing

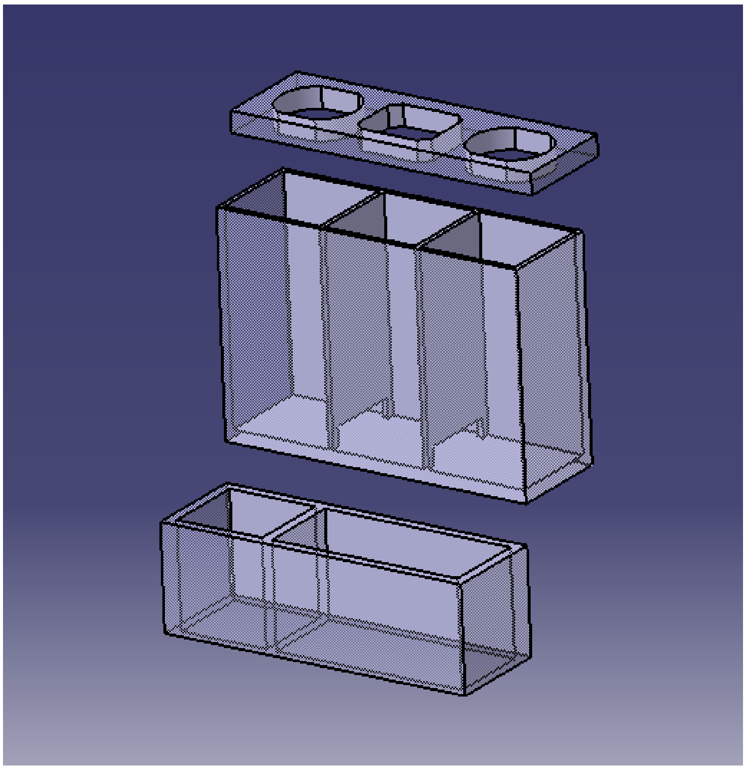


*Figure 9: Casing*

## 4. Final Product

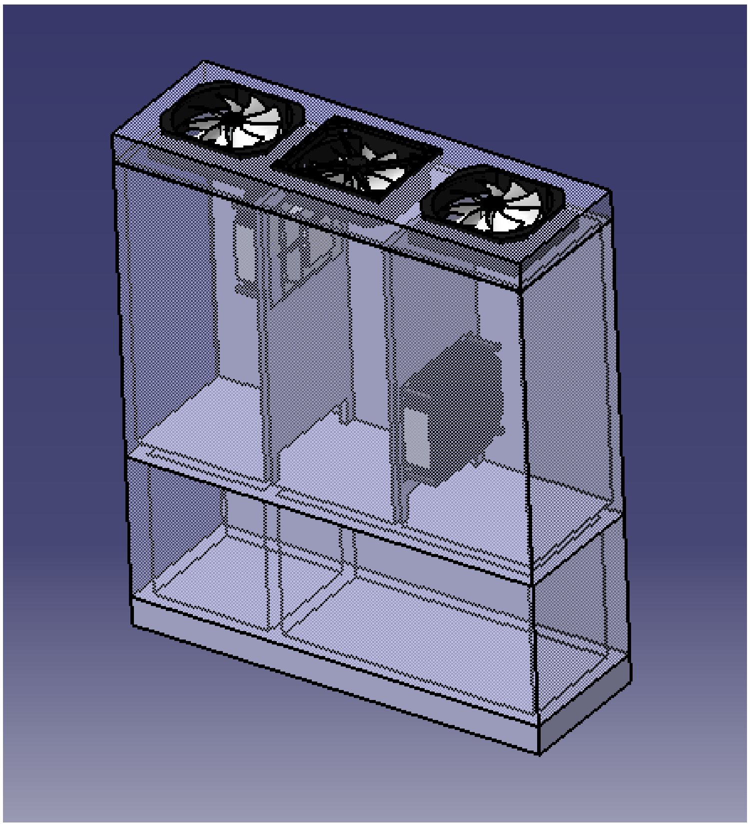


*Figure 10: Final Assembly*

## Components used

| Sl. no. | Component name | Quantity | Specification |
|---|---|---|---|
| 1. | Draft fan | 3 | DC 12V 0.16 Amp |
| 2. | Peltier | 2 | TEC 12706 |
| 3. | Heat sink | 2 | Heat sink of Pentium 4 motherboard |
| 4. | Casing | | Acrylic sheet |
| 5. | 400W PSU | 1 | Zebronics |

## Description

As can be seen from the CAD model the casing consists of three parts.

The upper part consists of three draft fans. The middle draft fan draws air from atmosphere into the device while the other two are used to expel the dehumidified air.

The middle part of the casing is further divided into three chambers. The inlet air is passed through the middle chamber where it comes in contact with the cold surface of the Peltier device. The inlet atmospheric air thus loses heat and its temperature falls to that of the dew point temperature and thus water starts condensing. The dehumidified air is then expelled from the device by the left and right chambers.

The lower part acts as a water collecting unit. Condensed water from the middle part is collected in this lower part by dripping action as water droplets are pulled down by gravitational force.

# *Chapter 4*

# Calculations

## 1. Dew point temperature calculation

**Definitions:**

**Dew-point temperature ($T_{dp}$)** is the temperature at which humidity in the air starts condensing at the same rate at which it is evaporating at a given constant barometric pressure.

**Dry-bulb temperature (DBT)** is the temperature of air measured by a thermometer freely exposed to the air but shielded from radiation and moisture. DBT is the temperature that is usually thought of as air temperature, and it is the true thermodynamic temperature.

**Relative humidity (RH)** is the ratio of the partial pressure of water vapour to the equilibrium vapour pressure of water at the same temperature.

The dew point is the saturation temperature for water in air. The dew point is associated with relative humidity. A high relative humidity implies that the dew point is closer to the current air temperature. Relative humidity of 100% indicates the dew point is equal to the current temperature and that the air is maximally saturated with water. When the moisture content remains constant and temperature increases, relative humidity decreases. [9]

This calculation forms an important part of this project as this helps us to determine at temperature the Peltier device must be maintained in order to condense the humidity present in air at the given atmospheric condition.

A well-known approximation used to calculate the dew point, $T_{dp}$, given just the actual ("dry bulb") air temperature, *T* and relative humidity (in percent), *RH*, is the *Magnus formula*:

$$\gamma(T, RH) = ln\left(\frac{RH}{100}\right) + \frac{bT}{c+T}$$

$$T_{dp} = \frac{c\gamma(T, RH)}{b - \gamma(T, RH)}$$

(Where, b = 17.67 & c = 243.5$^0$C and T is in $^0$C)

The above formulas is used to calculate the dew point temperature for different atmospheric conditions at which the device may be subjected to operate. With the help of Microsoft excel the operating parameters are calculated and tabulated.

**Sample Calculations:**

(for DBT=30$^0$c and RH=45%)

$$\gamma(30,45) = ln\left(\frac{45}{100}\right) + \frac{17.67 \times 30}{243.5 + 30} = 1.139$$

$$T_{dp} = \frac{243.5 \times 1.139}{17.67 - 1.139} = 16.77735769$$

The table for the dew point temperature calculation for different atmospheric conditions is as follows:

***Table 1: Dew point temperature calculations at 30$^0$C and different relative humidity conditions***

| **Dry Bulb Temp. (in C)** | **Relative Humidity (%)** | **Required Dew point Temp. (in C)** |
|---|---|---|
| 30 | 45 | 16.77735769 |
| 30 | 50 | 18.46356201 |
| 30 | 55 | 19.99121587 |
| 30 | 60 | 21.40183613 |
| 30 | 65 | 22.71309952 |
| 30 | 70 | 23.93889215 |
| 30 | 75 | 25.09032956 |
| 30 | 80 | 26.17645367 |
| 30 | 85 | 27.20472258 |
| 30 | 90 | 28.18136311 |
| 30 | 95 | 29.11163002 |
| 30 | 100 | 30 |

*Table 2: Dew point temperature calculations at 35$^0$C and different relative humidity conditions*

| Dry Bulb Temp. (in C) | Relative Humidity (%) | Required Dew point Temp. (in C) |
|---|---|---|
| 35 | 45 | 21.36839262 |
| 35 | 50 | 23.0900802 |
| 35 | 55 | 24.66719049 |
| 35 | 60 | 26.12347831 |
| 35 | 65 | 27.47719267 |
| 35 | 70 | 28.74266924 |
| 35 | 75 | 29.9313834 |
| 35 | 80 | 31.0526698 |
| 35 | 85 | 32.11422798 |
| 35 | 90 | 33.12248638 |
| 35 | 95 | 34.08286984 |
| 35 | 100 | 35 |

*Table 3: Dew point temperature calculations at 40$^0$C and different relative humidity conditions*

| Dry Bulb Temp. (in C) | Relative Humidity (%) | Required Dew point Temp. (in C) |
|---|---|---|
| 40 | 45 | 25.94092061 |
| 40 | 50 | 27.71659839 |
| 40 | 55 | 29.3431651 |
| 40 | 60 | 30.84512049 |
| 40 | 65 | 32.24128582 |
| 40 | 70 | 33.54644632 |
| 40 | 75 | 34.77243723 |
| 40 | 80 | 35.92888592 |
| 40 | 85 | 37.02373339 |
| 40 | 90 | 38.06360964 |
| 40 | 95 | 39.05410966 |
| 40 | 100 | 40 |

*Table 4: Dew point temperature calculations at 45$^0$C and different relative humidity conditions*

| Dry Bulb Temp. (in C) | Relative Humidity (%) | Required Dew point Temp. (in C) |
|---|---|---|
| 45 | 45 | 30.5134486 |
| 45 | 50 | 32.34311659 |
| 45 | 55 | 34.01913972 |
| 45 | 60 | 35.56676266 |
| 45 | 65 | 37.00537897 |
| 45 | 70 | 38.3502234 |
| 45 | 75 | 39.61349107 |
| 45 | 80 | 40.80510205 |
| 45 | 85 | 41.9332388 |
| 45 | 90 | 43.00473291 |
| 45 | 95 | 44.02534948 |
| 45 | 100 | 45 |

## 2. Amount of water (in L) present in 1m$^3$ of air for different humidity and temperature conditions

**Definitions:**

**Saturation Pressure ($P_s$)** is the pressure of a vapour which is in equilibrium with its liquid (as steam with water) i.e. the maximum pressure possible by water vapour at a given temperature. The saturation pressure of water at different atmospheric temperature is obtained from the commercially available steam tables.

Air is a mixture of both air molecules and water molecules. **Partial Pressure of water ($P_w$)** is the pressure of water vapour present in a mixture of air and water vapour. [10]

**Relative Humidity (RH)** is the ratio of partial pressure of water ($P_w$) to that of saturation pressure ($P_s$) i.e.

$$RH = \frac{P_w}{P_s} \times 100$$

Thus from saturation pressure ($P_s$) and relative humidity (RH) data partial pressure of water ($P_w$) can be obtained as

$$P_w = \frac{RH}{100} \times P_s$$

**Humidity Ratio** gives the volume of water (in $m^3$) present in $1m^3$ of air.

Humidity ratio can also be expressed in terms of partial pressure of water ($P_w$) as

$$Humidity\ Ratio = 0.622 \times \frac{P_w}{P_a - P_w}$$

(Where $P_a$ is the atmospheric pressure i.e. $P_a$=1.01325 bar)

Humidity ratio gives the amount of water (in $m^3$) present in $1m^3$ of air. Also we know that $1m^3$ is equal to 1000 litres. Thus multiplying humidity ratio by 1000 gives the maximum amount of water (in litres) that is present in $1m^3$ of air.

**Sample Calculations:**

(For atmospheric temperature $25^0$C and relative humidity 35%)

Saturation Pressure of water vapour ($P_w$) at $25^0$C is obtained from steam table as 0.03167 bar.

Thus Partial pressure of water, $P_w = \frac{RH}{100} \times P_s = \frac{35}{100} \times 0.03167 = 0.0110845$ bar

Humidity Ratio = $0.622 \times \frac{P_w}{P_a - P_w} = 0.622 \times \frac{0.0110845}{1.01325 - 0.0110845} = 0.006879661$

Therefore amount of water (in litres) present in $1m^3$ of atmospheric air

$= Humidity\ ratio \times 1000 = 0.006879661 \times 1000 = 6.879661$ litres

The amount of water present in $1m^3$ of air consisting of the above mentioned calculations for different atmospheric conditions are tabulated below:

***Table 5: Amount of water which can be obtained by processing 1m³ of air at 35% relative humidity for different temperature conditions***

| Temp. | Saturation Pressure-$P_s$ (in bar) from psychometric chart | Relative Humidity (in %) | Partial Pressure of water-$P_w$ (in bar) | Humidity Ratio (Amount of water in 1m^3 of air) | Amount of water (in l) |
|---|---|---|---|---|---|
| 25 | 0.03167 | 35 | 0.0110845 | 0.006879661 | 6.879661094 |
| 26 | 0.03361 | 35 | 0.0117635 | 0.007306037 | 7.306036577 |
| 27 | 0.03565 | 35 | 0.0124775 | 0.007755014 | 7.755014251 |
| 28 | 0.03779 | 35 | 0.0132265 | 0.00822669 | 8.226689673 |
| 29 | 0.04005 | 35 | 0.0140175 | 0.008725582 | 8.725581884 |
| 30 | 0.04241 | 35 | 0.0148435 | 0.009247393 | 9.24739272 |
| 31 | 0.04492 | 35 | 0.015722 | 0.009803318 | 9.803317802 |
| 32 | 0.04755 | 35 | 0.0166425 | 0.010386872 | 10.38687246 |
| 33 | 0.05031 | 35 | 0.0176085 | 0.011000432 | 11.00043238 |
| 34 | 0.0532 | 35 | 0.01862 | 0.011644169 | 11.64416919 |
| 35 | 0.05624 | 35 | 0.019684 | 0.012322732 | 12.32273246 |
| 36 | 0.05942 | 35 | 0.020797 | 0.013034102 | 13.03410237 |
| 37 | 0.06276 | 35 | 0.021966 | 0.013782984 | 13.78298449 |
| 38 | 0.06626 | 35 | 0.023191 | 0.014569639 | 14.56963878 |
| 39 | 0.06992 | 35 | 0.024472 | 0.015394339 | 15.39433928 |
| 40 | 0.07376 | 35 | 0.025816 | 0.016261899 | 16.26189902 |
| 41 | 0.07779 | 35 | 0.0272265 | 0.017174928 | 17.17492839 |
| 42 | 0.08201 | 35 | 0.0287035 | 0.018133808 | 18.1338078 |
| 43 | 0.08642 | 35 | 0.030247 | 0.019138939 | 19.13893854 |
| 44 | 0.09103 | 35 | 0.0318605 | 0.020193033 | 20.19303345 |
| 45 | 0.09585 | 35 | 0.0335475 | 0.021298859 | 21.29885858 |

*Table 6: Amount of water which can be obtained by processing 1m$^3$ of air at 40% relative humidity for different temperature conditions*

| Temp. | Saturation Pressure-Ps (in bar) from psychometric chart | Relative Humidity (in %) | Partial Pressure of water-Pw (in bar) | Humidity Ratio (Amount of water in 1m^3 of air) | Amount of water (in l) |
|---|---|---|---|---|---|
| 25 | 0.03167 | 40 | 0.012668 | 0.007874913 | 7.874912801 |
| 26 | 0.03361 | 40 | 0.013444 | 0.008363791 | 8.363790575 |
| 27 | 0.03565 | 40 | 0.01426 | 0.008878687 | 8.878687474 |
| 28 | 0.03779 | 40 | 0.015116 | 0.009419729 | 9.419729215 |
| 29 | 0.04005 | 40 | 0.01602 | 0.009992118 | 9.992118167 |
| 30 | 0.04241 | 40 | 0.016964 | 0.010590943 | 10.59094276 |
| 31 | 0.04492 | 40 | 0.017968 | 0.011229075 | 11.22907477 |
| 32 | 0.04755 | 40 | 0.01902 | 0.011899098 | 11.89909779 |
| 33 | 0.05031 | 40 | 0.020124 | 0.012603766 | 12.60376629 |
| 34 | 0.0532 | 40 | 0.02128 | 0.013343307 | 13.34330675 |
| 35 | 0.05624 | 40 | 0.022496 | 0.014123094 | 14.12309413 |
| 36 | 0.05942 | 40 | 0.023768 | 0.014940844 | 14.9408438 |
| 37 | 0.06276 | 40 | 0.025104 | 0.015802005 | 15.80200497 |
| 38 | 0.06626 | 40 | 0.026504 | 0.016706922 | 16.70692154 |
| 39 | 0.06992 | 40 | 0.027968 | 0.017655956 | 17.65595637 |
| 40 | 0.07376 | 40 | 0.029504 | 0.018654702 | 18.65470152 |
| 41 | 0.07779 | 40 | 0.031116 | 0.019706223 | 19.70622339 |
| 42 | 0.08201 | 40 | 0.032804 | 0.020811027 | 20.81102682 |
| 43 | 0.08642 | 40 | 0.034568 | 0.021969645 | 21.96964489 |
| 44 | 0.09103 | 40 | 0.036412 | 0.023185281 | 23.18528149 |
| 45 | 0.09585 | 40 | 0.03834 | 0.024461212 | 24.4612118 |

*Table 7: Amount of water which can be obtained by processing 1m$^3$ of air at 45% relative humidity for different temperature conditions*

| Temp. | Saturation Pressure-Ps (in bar) from psychometric chart | Relative Humidity (in %) | Partial Pressure of water-Pw (in bar) | Humidity Ratio (Amount of water in 1m^3 of air) | Amount of water (in l) |
|---|---|---|---|---|---|
| 25 | 0.03167 | 45 | 0.0142515 | 0.00887332 | 8.87331963 |
| 26 | 0.03361 | 45 | 0.0151245 | 0.009425106 | 9.425106362 |
| 27 | 0.03565 | 45 | 0.0160425 | 0.010006378 | 10.00637781 |
| 28 | 0.03779 | 45 | 0.0170055 | 0.010617294 | 10.61729425 |
| 29 | 0.04005 | 45 | 0.0180225 | 0.011263751 | 11.26375125 |
| 30 | 0.04241 | 45 | 0.0190845 | 0.011940224 | 11.94022424 |
| 31 | 0.04492 | 45 | 0.020214 | 0.012661281 | 12.66128116 |
| 32 | 0.04755 | 45 | 0.0213975 | 0.013418573 | 13.41857282 |
| 33 | 0.05031 | 45 | 0.0226395 | 0.014215243 | 14.21524302 |
| 34 | 0.0532 | 45 | 0.02394 | 0.015051581 | 15.05158141 |
| 35 | 0.05624 | 45 | 0.025308 | 0.015933705 | 15.93370461 |
| 36 | 0.05942 | 45 | 0.026739 | 0.01685907 | 16.85907 |
| 37 | 0.06276 | 45 | 0.028242 | 0.01783389 | 17.83388967 |
| 38 | 0.06626 | 45 | 0.029817 | 0.018858605 | 18.8586045 |
| 39 | 0.06992 | 45 | 0.031464 | 0.01993368 | 19.93368005 |
| 40 | 0.07376 | 45 | 0.033192 | 0.021065512 | 21.06551245 |
| 41 | 0.07779 | 45 | 0.0350055 | 0.022257647 | 22.25764724 |
| 42 | 0.08201 | 45 | 0.0369045 | 0.023510734 | 23.51073365 |
| 43 | 0.08642 | 45 | 0.038889 | 0.024825458 | 24.82545792 |
| 44 | 0.09103 | 45 | 0.0409635 | 0.026205544 | 26.20554435 |
| 45 | 0.09585 | 45 | 0.0431325 | 0.02765481 | 27.65480986 |

*Table 8: Amount of water which can be obtained by processing 1m$^3$ of air at 50% relative humidity for different temperature conditions*

| Temp. | Saturation Pressure-Ps (in bar) from psychometric chart | Relative Humidity (in %) | Partial Pressure of water-Pw (in bar) | Humidity Ratio (Amount of water in 1m^3 of air) | Amount of water (in l) |
|---|---|---|---|---|---|
| 25 | 0.03167 | 50 | 0.015835 | 0.009874897 | 9.874896608 |
| 26 | 0.03361 | 50 | 0.016805 | 0.010490002 | 10.49000196 |
| 27 | 0.03565 | 50 | 0.017825 | 0.011138107 | 11.13810684 |
| 28 | 0.03779 | 50 | 0.018895 | 0.011819411 | 11.81941057 |
| 29 | 0.04005 | 50 | 0.020025 | 0.012540512 | 12.54051197 |
| 30 | 0.04241 | 50 | 0.021205 | 0.013295274 | 13.2952739 |
| 31 | 0.04492 | 50 | 0.02246 | 0.014099981 | 14.09998082 |
| 32 | 0.04755 | 50 | 0.023775 | 0.01494535 | 14.94534981 |
| 33 | 0.05031 | 50 | 0.025155 | 0.015834925 | 15.83492478 |
| 34 | 0.0532 | 50 | 0.0266 | 0.016769067 | 16.76906705 |
| 35 | 0.05624 | 50 | 0.02812 | 0.017754652 | 17.75465167 |
| 36 | 0.05942 | 50 | 0.02971 | 0.018788885 | 18.78888505 |
| 37 | 0.06276 | 50 | 0.03138 | 0.019878762 | 19.87876195 |
| 38 | 0.06626 | 50 | 0.03313 | 0.021024834 | 21.02483369 |
| 39 | 0.06992 | 50 | 0.03496 | 0.022227683 | 22.227683 |
| 40 | 0.07376 | 50 | 0.03688 | 0.023494536 | 23.49453588 |
| 41 | 0.07779 | 50 | 0.038895 | 0.024829441 | 24.82944101 |
| 42 | 0.08201 | 50 | 0.041005 | 0.026233213 | 26.23321282 |
| 43 | 0.08642 | 50 | 0.04321 | 0.027706713 | 27.70671313 |
| 44 | 0.09103 | 50 | 0.045515 | 0.029254217 | 29.25421732 |
| 45 | 0.09585 | 50 | 0.047925 | 0.030880118 | 30.88011809 |

*Table 9: Amount of water which can be obtained by processing 1m$^3$ of air at 55% relative humidity for different temperature conditions*

| Temp. | Saturation Pressure-Ps (in bar) from psychometric chart | Relative Humidity (in %) | Partial Pressure of water-Pw (in bar) | Humidity Ratio (Amount of water in 1m^3 of air) | Amount of water (in l) |
|---|---|---|---|---|---|
| 25 | 0.03167 | 55 | 0.0174185 | 0.010879659 | 10.87965886 |
| 26 | 0.03361 | 55 | 0.0184855 | 0.011558496 | 11.5584955 |
| 27 | 0.03565 | 55 | 0.0196075 | 0.012273896 | 12.2738963 |
| 28 | 0.03779 | 55 | 0.0207845 | 0.013026104 | 13.02610418 |
| 29 | 0.04005 | 55 | 0.0220275 | 0.013822431 | 13.82243139 |
| 30 | 0.04241 | 55 | 0.0233255 | 0.014656129 | 14.65612883 |
| 31 | 0.04492 | 55 | 0.024706 | 0.015545218 | 15.54521802 |
| 32 | 0.04755 | 55 | 0.0261525 | 0.016479482 | 16.47948151 |
| 33 | 0.05031 | 55 | 0.0276705 | 0.017462874 | 17.46287438 |
| 34 | 0.0532 | 55 | 0.02926 | 0.018495838 | 18.49583837 |
| 35 | 0.05624 | 55 | 0.030932 | 0.019586024 | 19.58602408 |
| 36 | 0.05942 | 55 | 0.032681 | 0.020730394 | 20.73039429 |
| 37 | 0.06276 | 55 | 0.034518 | 0.021936747 | 21.93674673 |
| 38 | 0.06626 | 55 | 0.036443 | 0.023205757 | 23.20575713 |
| 39 | 0.06992 | 55 | 0.038456 | 0.02453814 | 24.53814037 |
| 40 | 0.07376 | 55 | 0.040568 | 0.025941979 | 25.94197898 |
| 41 | 0.07779 | 55 | 0.0427845 | 0.02742185 | 27.42184962 |
| 42 | 0.08201 | 55 | 0.0451055 | 0.028978754 | 28.97875369 |
| 43 | 0.08642 | 55 | 0.047531 | 0.030613752 | 30.61375203 |
| 44 | 0.09103 | 55 | 0.0500665 | 0.032331703 | 32.33170315 |
| 45 | 0.09585 | 55 | 0.0527175 | 0.034137611 | 34.13761117 |

***Table 10: Amount of water which can be obtained by processing 1m$^3$ of air at 60% relative humidity for different temperature conditions***

| **Temp.** | **Saturation Pressure-Ps (in bar) from psychometric chart** | **Relative Humidity (in %)** | **Partial Pressure of water-Pw (in bar)** | **Humidity Ratio (Amount of water in 1m^3 of air)** | **Amount of water (in l)** |
|---|---|---|---|---|---|
| 25 | 0.03167 | 60 | 0.019002 | 0.011887622 | 11.8876216 |
| 26 | 0.03361 | 60 | 0.020166 | 0.012630605 | 12.63060527 |
| 27 | 0.03565 | 60 | 0.02139 | 0.013413768 | 13.41376807 |
| 28 | 0.03779 | 60 | 0.022674 | 0.014237401 | 14.23740127 |
| 29 | 0.04005 | 60 | 0.02403 | 0.015109541 | 15.10954085 |
| 30 | 0.04241 | 60 | 0.025446 | 0.016022826 | 16.02282639 |
| 31 | 0.04492 | 60 | 0.026952 | 0.016997037 | 16.99703741 |
| 32 | 0.04755 | 60 | 0.02853 | 0.018021021 | 18.0210212 |
| 33 | 0.05031 | 60 | 0.030186 | 0.019099155 | 19.09915529 |
| 34 | 0.0532 | 60 | 0.03192 | 0.020231971 | 20.2319709 |
| 35 | 0.05624 | 60 | 0.033744 | 0.021427912 | 21.42791162 |
| 36 | 0.05942 | 60 | 0.035652 | 0.022683704 | 22.68370434 |
| 37 | 0.06276 | 60 | 0.037656 | 0.024007971 | 24.00797053 |
| 38 | 0.06626 | 60 | 0.039756 | 0.025401525 | 25.40152482 |
| 39 | 0.06992 | 60 | 0.041952 | 0.02686523 | 26.86522983 |
| 40 | 0.07376 | 60 | 0.044256 | 0.028408052 | 28.40805206 |
| 41 | 0.07779 | 60 | 0.046674 | 0.030035122 | 30.03512191 |
| 42 | 0.08201 | 60 | 0.049206 | 0.031747651 | 31.74765052 |
| 43 | 0.08642 | 60 | 0.051852 | 0.033546922 | 33.54692229 |
| 44 | 0.09103 | 60 | 0.054618 | 0.035438412 | 35.43841224 |
| 45 | 0.09585 | 60 | 0.05751 | 0.037427773 | 37.42777324 |

*Table 11: Amount of water which can be obtained by processing 1m$^3$ of air at 65% relative humidity for different temperature conditions*

| Temp. | Saturation Pressure-Ps (in bar) from psychometric chart | Relative Humidity (in %) | Partial Pressure of water-Pw (in bar) | Humidity Ratio (Amount of water in 1m^3 of air) | Amount of water (in l) |
|---|---|---|---|---|---|
| 25 | 0.03167 | 65 | 0.0205855 | 0.0128988 | 12.89880015 |
| 26 | 0.03361 | 65 | 0.0218465 | 0.01370635 | 13.70634963 |
| 27 | 0.03565 | 65 | 0.0231725 | 0.014557744 | 14.55774422 |
| 28 | 0.03779 | 65 | 0.0245635 | 0.015453328 | 15.45332823 |
| 29 | 0.04005 | 65 | 0.0260325 | 0.016401872 | 16.40187193 |
| 30 | 0.04241 | 65 | 0.0275665 | 0.017395404 | 17.39540431 |
| 31 | 0.04492 | 65 | 0.029198 | 0.018455484 | 18.45548406 |
| 32 | 0.04755 | 65 | 0.0309075 | 0.019570023 | 19.57002268 |
| 33 | 0.05031 | 65 | 0.0327015 | 0.020743832 | 20.74383164 |
| 34 | 0.0532 | 65 | 0.03458 | 0.021977541 | 21.97754095 |
| 35 | 0.05624 | 65 | 0.036556 | 0.023280405 | 23.28040512 |
| 36 | 0.05942 | 65 | 0.038623 | 0.024648923 | 24.64892313 |
| 37 | 0.06276 | 65 | 0.040794 | 0.026092562 | 26.09256151 |
| 38 | 0.06626 | 65 | 0.043069 | 0.027612289 | 27.61228884 |
| 39 | 0.06992 | 65 | 0.045448 | 0.029209132 | 29.20913162 |
| 40 | 0.07376 | 65 | 0.047944 | 0.030892969 | 30.89296865 |
| 41 | 0.07779 | 65 | 0.0505635 | 0.032669511 | 32.66951079 |
| 42 | 0.08201 | 65 | 0.0533065 | 0.034540203 | 34.54020263 |
| 43 | 0.08642 | 65 | 0.056173 | 0.036506578 | 36.50657784 |
| 44 | 0.09103 | 65 | 0.0591695 | 0.038574763 | 38.57476282 |
| 45 | 0.09585 | 65 | 0.0623025 | 0.040751098 | 40.75109825 |

*Table 12: Amount of water which can be obtained by processing 1m$^3$ of air at 70% relative humidity for different temperature conditions*

| Temp. | Saturation Pressure-Ps (in bar) from psychometric chart | Relative Humidity (in %) | Partial Pressure of water-Pw (in bar) | Humidity Ratio (Amount of water in 1m^3 of air) | Amount of water (in l) |
|---|---|---|---|---|---|
| 25 | 0.03167 | 70 | 0.022169 | 0.01391321 | 13.91320992 |
| 26 | 0.03361 | 70 | 0.023527 | 0.014785747 | 14.78574712 |
| 27 | 0.03565 | 70 | 0.024955 | 0.015705847 | 15.70584694 |
| 28 | 0.03779 | 70 | 0.026453 | 0.016673912 | 16.67391166 |
| 29 | 0.04005 | 70 | 0.028035 | 0.017699456 | 17.69945646 |
| 30 | 0.04241 | 70 | 0.029687 | 0.018773901 | 18.7739006 |
| 31 | 0.04492 | 70 | 0.031444 | 0.019920603 | 19.92060346 |
| 32 | 0.04755 | 70 | 0.033285 | 0.02112654 | 21.12654023 |
| 33 | 0.05031 | 70 | 0.035217 | 0.022396968 | 22.3969682 |
| 34 | 0.0532 | 70 | 0.03724 | 0.023732626 | 23.73262569 |
| 35 | 0.05624 | 70 | 0.039368 | 0.025143596 | 25.14359645 |
| 36 | 0.05942 | 70 | 0.041594 | 0.02662616 | 26.62615988 |
| 37 | 0.06276 | 70 | 0.043932 | 0.02819065 | 28.19064951 |
| 38 | 0.06626 | 70 | 0.046382 | 0.029838203 | 29.83820335 |
| 39 | 0.06992 | 70 | 0.048944 | 0.031570029 | 31.5700286 |
| 40 | 0.07376 | 70 | 0.051632 | 0.033396946 | 33.39694556 |
| 41 | 0.07779 | 70 | 0.054453 | 0.035325273 | 35.32527323 |
| 42 | 0.08201 | 70 | 0.057407 | 0.037356714 | 37.35671444 |
| 43 | 0.08642 | 70 | 0.060494 | 0.039493079 | 39.49307903 |
| 44 | 0.09103 | 70 | 0.063721 | 0.041741181 | 41.74118115 |
| 45 | 0.09585 | 70 | 0.067095 | 0.04410809 | 44.10809011 |

*Table 13: Amount of water which can be obtained by processing 1m$^3$ of air at 75% relative humidity for different temperature conditions*

| Temp. | Saturation Pressure-Ps (in bar) from psychometric chart | Relative Humidity (in %) | Partial Pressure of water-Pw (in bar) | Humidity Ratio (Amount of water in 1m^3 of air) | Amount of water (in l) |
|---|---|---|---|---|---|
| 25 | 0.03167 | 75 | 0.0237525 | 0.014930866 | 14.93086642 |
| 26 | 0.03361 | 75 | 0.0252075 | 0.015868816 | 15.86881637 |
| 27 | 0.03565 | 75 | 0.0267375 | 0.016858099 | 16.8580986 |
| 28 | 0.03779 | 75 | 0.0283425 | 0.017899178 | 17.89917835 |
| 29 | 0.04005 | 75 | 0.0300375 | 0.019002327 | 19.00232656 |
| 30 | 0.04241 | 75 | 0.0318075 | 0.020158354 | 20.15835365 |
| 31 | 0.04492 | 75 | 0.03369 | 0.021392442 | 21.3924415 |
| 32 | 0.04755 | 75 | 0.0356625 | 0.022690629 | 22.69062872 |
| 33 | 0.05031 | 75 | 0.0377325 | 0.02405863 | 24.05863042 |
| 34 | 0.0532 | 75 | 0.0399 | 0.025497303 | 25.49730313 |
| 35 | 0.05624 | 75 | 0.04218 | 0.027017579 | 27.01757855 |
| 36 | 0.05942 | 75 | 0.044565 | 0.028615525 | 28.61552517 |
| 37 | 0.06276 | 75 | 0.04707 | 0.030302366 | 30.30236602 |
| 38 | 0.06626 | 75 | 0.049695 | 0.032079425 | 32.07942463 |
| 39 | 0.06992 | 75 | 0.05244 | 0.033948106 | 33.94810629 |
| 40 | 0.07376 | 75 | 0.05532 | 0.035920203 | 35.92020294 |
| 41 | 0.07779 | 75 | 0.0583425 | 0.03800267 | 38.00267042 |
| 42 | 0.08201 | 75 | 0.0615075 | 0.040197496 | 40.19749565 |
| 43 | 0.08642 | 75 | 0.064815 | 0.042506793 | 42.50679277 |
| 44 | 0.09103 | 75 | 0.0682725 | 0.044938102 | 44.9381017 |
| 45 | 0.09585 | 75 | 0.0718875 | 0.047499263 | 47.49926304 |

***Table 14: Amount of water which can be obtained by processing 1m$^3$ of air at 80% relative humidity for different temperature conditions***

| Temp. | Saturation Pressure-Ps (in bar) from psychometric chart | Relative Humidity (in %) | Partial Pressure of water-Pw (in bar) | Humidity Ratio (Amount of water in 1m^3 of air) | Amount of water (in l) |
|---|---|---|---|---|---|
| 25 | 0.03167 | 80 | 0.025336 | 0.015951785 | 15.95178528 |
| 26 | 0.03361 | 80 | 0.026888 | 0.016955576 | 16.95557615 |
| 27 | 0.03565 | 80 | 0.02852 | 0.018014522 | 18.01452175 |
| 28 | 0.03779 | 80 | 0.030232 | 0.019129155 | 19.12915532 |
| 29 | 0.04005 | 80 | 0.03204 | 0.020310515 | 20.31051457 |
| 30 | 0.04241 | 80 | 0.033928 | 0.021548802 | 21.54880213 |
| 31 | 0.04492 | 80 | 0.035936 | 0.022871045 | 22.87104452 |
| 32 | 0.04755 | 80 | 0.03804 | 0.024262343 | 24.2623435 |
| 33 | 0.05031 | 80 | 0.040248 | 0.025728884 | 25.72888442 |
| 34 | 0.0532 | 80 | 0.04256 | 0.027271652 | 27.27165212 |
| 35 | 0.05624 | 80 | 0.044992 | 0.028902445 | 28.90244542 |
| 36 | 0.05942 | 80 | 0.047536 | 0.030617131 | 30.61713095 |
| 37 | 0.06276 | 80 | 0.050208 | 0.032427844 | 32.42784427 |
| 38 | 0.06626 | 80 | 0.053008 | 0.034336111 | 34.33611111 |
| 39 | 0.06992 | 80 | 0.055936 | 0.036343553 | 36.3435529 |
| 40 | 0.07376 | 80 | 0.059008 | 0.038462964 | 38.46296432 |
| 41 | 0.07779 | 80 | 0.062232 | 0.040701968 | 40.70196779 |
| 42 | 0.08201 | 80 | 0.065608 | 0.043062861 | 43.06286129 |
| 43 | 0.08642 | 80 | 0.069136 | 0.045548093 | 45.54809271 |
| 44 | 0.09103 | 80 | 0.072824 | 0.048165967 | 48.16596734 |
| 45 | 0.09585 | 80 | 0.07668 | 0.050925142 | 50.92514174 |

***Table 15: Amount of water which can be obtained by processing 1m$^3$ of air at 85% relative humidity for different temperature conditions***

| Temp. | Saturation Pressure-Ps (in bar) from psychometric chart | Relative Humidity (in %) | Partial Pressure of water-Pw (in bar) | Humidity Ratio (Amount of water in 1m^3 of air) | Amount of water (in l) |
|---|---|---|---|---|---|
| 25 | 0.03167 | 85 | 0.0269195 | 0.016975982 | 16.97598219 |
| 26 | 0.03361 | 85 | 0.0285685 | 0.018046045 | 18.04604535 |
| 27 | 0.03565 | 85 | 0.0303025 | 0.019175139 | 19.17513906 |
| 28 | 0.03779 | 85 | 0.0321215 | 0.02036387 | 20.36386977 |
| 29 | 0.04005 | 85 | 0.0340425 | 0.021624053 | 21.62405312 |
| 30 | 0.04241 | 85 | 0.0360485 | 0.022945285 | 22.94528508 |
| 31 | 0.04492 | 85 | 0.038182 | 0.024356459 | 24.35645924 |
| 32 | 0.04755 | 85 | 0.0404175 | 0.02584174 | 25.84174048 |
| 33 | 0.05031 | 85 | 0.0427635 | 0.027407797 | 27.40779702 |
| 34 | 0.0532 | 85 | 0.04522 | 0.029055752 | 29.0557524 |
| 35 | 0.05624 | 85 | 0.047804 | 0.030798292 | 30.79829219 |
| 36 | 0.05942 | 85 | 0.050507 | 0.032631091 | 32.63109054 |
| 37 | 0.06276 | 85 | 0.053346 | 0.034567219 | 34.56721922 |
| 38 | 0.06626 | 85 | 0.056321 | 0.036608423 | 36.6084234 |
| 39 | 0.06992 | 85 | 0.059432 | 0.038756559 | 38.75655943 |
| 40 | 0.07376 | 85 | 0.062696 | 0.041025457 | 41.02545673 |
| 41 | 0.07779 | 85 | 0.0661215 | 0.043423435 | 43.42343515 |
| 42 | 0.08201 | 85 | 0.0697085 | 0.045953132 | 45.9531319 |
| 43 | 0.08642 | 85 | 0.073457 | 0.048617359 | 48.61735935 |
| 44 | 0.09103 | 85 | 0.0773755 | 0.05142523 | 51.42522956 |
| 45 | 0.09585 | 85 | 0.0814725 | 0.054386262 | 54.38626174 |

*Table 16: Amount of water which can be obtained by processing 1m$^3$ of air at 90% relative humidity for different temperature conditions*

| Temp. | Saturation Pressure-Ps (in bar) from psychometric chart | Relative Humidity (in %) | Partial Pressure of water-Pw (in bar) | Humidity Ratio (Amount of water in 1m^3 of air) | Amount of water (in l) |
|---|---|---|---|---|---|
| 25 | 0.03167 | 90 | 0.028503 | 0.018003473 | 18.00347297 |
| 26 | 0.03361 | 90 | 0.030249 | 0.019140243 | 19.14024299 |
| 27 | 0.03565 | 90 | 0.032085 | 0.020339973 | 20.3399734 |
| 28 | 0.03779 | 90 | 0.034011 | 0.021603349 | 21.60334913 |
| 29 | 0.04005 | 90 | 0.036045 | 0.022942975 | 22.94297512 |
| 30 | 0.04241 | 90 | 0.038169 | 0.024347842 | 24.34784187 |
| 31 | 0.04492 | 90 | 0.040428 | 0.025848733 | 25.84873286 |
| 32 | 0.04755 | 90 | 0.042795 | 0.027428876 | 27.42887615 |
| 33 | 0.05031 | 90 | 0.045279 | 0.029095436 | 29.09543571 |
| 34 | 0.0532 | 90 | 0.04788 | 0.030849685 | 30.84968458 |
| 35 | 0.05624 | 90 | 0.050616 | 0.032705215 | 32.70521507 |
| 36 | 0.05942 | 90 | 0.053478 | 0.034657519 | 34.65751866 |
| 37 | 0.06276 | 90 | 0.056484 | 0.036720628 | 36.72062761 |
| 38 | 0.06626 | 90 | 0.059634 | 0.038896524 | 38.89652439 |
| 39 | 0.06992 | 90 | 0.062928 | 0.04118732 | 41.18731967 |
| 40 | 0.07376 | 90 | 0.066384 | 0.043607911 | 43.60791073 |
| 41 | 0.07779 | 90 | 0.070011 | 0.046167347 | 46.16734677 |
| 42 | 0.08201 | 90 | 0.073809 | 0.048868634 | 48.86863358 |
| 43 | 0.08642 | 90 | 0.077778 | 0.05171498 | 51.71498025 |
| 44 | 0.09103 | 90 | 0.081927 | 0.054716349 | 54.71634868 |
| 45 | 0.09585 | 90 | 0.086265 | 0.05788317 | 57.88316963 |

*Table 17: Amount of water which can be obtained by processing 1m$^3$ of air at 95% relative humidity for different temperature conditions*

| Temp. | Saturation Pressure-Ps (in bar) from psychometric chart | Relative Humidity (in %) | Partial Pressure of water-Pw (in bar) | Humidity Ratio (Amount of water in 1m^3 of air) | Amount of water (in l) |
|---|---|---|---|---|---|
| 25 | 0.03167 | 95 | 0.0300865 | 0.019034274 | 19.03427355 |
| 26 | 0.03361 | 95 | 0.0319295 | 0.020238188 | 20.23818824 |
| 27 | 0.03565 | 95 | 0.0338675 | 0.021509048 | 21.50904779 |
| 28 | 0.03779 | 95 | 0.0359005 | 0.022847621 | 22.84762104 |
| 29 | 0.04005 | 95 | 0.0380475 | 0.024267314 | 24.26731371 |
| 30 | 0.04241 | 95 | 0.0402895 | 0.025756512 | 25.75651221 |
| 31 | 0.04492 | 95 | 0.042674 | 0.027347913 | 27.34791299 |
| 32 | 0.04755 | 95 | 0.0451725 | 0.029023807 | 29.02380749 |
| 33 | 0.05031 | 95 | 0.0477945 | 0.030791869 | 30.79186871 |
| 34 | 0.0532 | 95 | 0.05054 | 0.03265353 | 32.65353014 |
| 35 | 0.05624 | 95 | 0.053428 | 0.034623311 | 34.62331141 |
| 36 | 0.05942 | 95 | 0.056449 | 0.036696531 | 36.69653146 |
| 37 | 0.06276 | 95 | 0.059622 | 0.038888208 | 38.88820798 |
| 38 | 0.06626 | 95 | 0.062947 | 0.041200579 | 41.20057918 |
| 39 | 0.06992 | 95 | 0.066424 | 0.04363603 | 43.63603027 |
| 40 | 0.07376 | 95 | 0.070072 | 0.04621056 | 46.21056047 |
| 41 | 0.07779 | 95 | 0.0739005 | 0.048933981 | 48.93398144 |
| 42 | 0.08201 | 95 | 0.0779095 | 0.051809698 | 51.80969818 |
| 43 | 0.08642 | 95 | 0.082099 | 0.05484135 | 54.84135011 |
| 44 | 0.09103 | 95 | 0.0864785 | 0.058039794 | 58.03979406 |
| 45 | 0.09585 | 95 | 0.0910575 | 0.061416423 | 61.41642336 |

*Table 18: Amount of water which can be obtained by processing 1m$^3$ of air at 100% relative humidity for different temperature conditions*

| Temp. | Saturation Pressure-Ps (in bar) from psychometric chart | Relative Humidity (in %) | Partial Pressure of water-Pw (in bar) | Humidity Ratio (Amount of water in 1m^3 of air) | Amount of water (in l) |
|---|---|---|---|---|---|
| 25 | 0.03167 | 100 | 0.03167 | 0.0200684 | 20.06839993 |
| 26 | 0.03361 | 100 | 0.03361 | 0.0213399 | 21.33990037 |
| 27 | 0.03565 | 100 | 0.03565 | 0.022682385 | 22.68238543 |
| 28 | 0.03779 | 100 | 0.03779 | 0.024096713 | 24.09671335 |
| 29 | 0.04005 | 100 | 0.04005 | 0.025597102 | 25.59710234 |
| 30 | 0.04241 | 100 | 0.04241 | 0.027171336 | 27.17133616 |
| 31 | 0.04492 | 100 | 0.04492 | 0.028854048 | 28.85404769 |
| 32 | 0.04755 | 100 | 0.04755 | 0.030626592 | 30.62659211 |
| 33 | 0.05031 | 100 | 0.05031 | 0.032497165 | 32.49716493 |
| 34 | 0.0532 | 100 | 0.0532 | 0.034467371 | 34.46737149 |
| 35 | 0.05624 | 100 | 0.05624 | 0.03655268 | 36.5526797 |
| 36 | 0.05942 | 100 | 0.05942 | 0.038748247 | 38.74824654 |
| 37 | 0.06276 | 100 | 0.06276 | 0.041070101 | 41.07010068 |
| 38 | 0.06626 | 100 | 0.06626 | 0.043520755 | 43.52075524 |
| 39 | 0.06992 | 100 | 0.06992 | 0.046102891 | 46.10289082 |
| 40 | 0.07376 | 100 | 0.07376 | 0.048833644 | 48.83364379 |
| 41 | 0.07779 | 100 | 0.07779 | 0.051723623 | 51.7236226 |
| 42 | 0.08201 | 100 | 0.08201 | 0.054776663 | 54.77666337 |
| 43 | 0.08642 | 100 | 0.08642 | 0.057996871 | 57.99687106 |
| 44 | 0.09103 | 100 | 0.09103 | 0.061396044 | 61.39604433 |
| 45 | 0.09585 | 100 | 0.09585 | 0.064986593 | 64.98659254 |

# *Chapter-5*

# ANSYS (Fluent) Analysis

Different steps which were followed for the analysis are given below:

**Step 1: Geometry**

First the model is imported to ANSYS workbench.

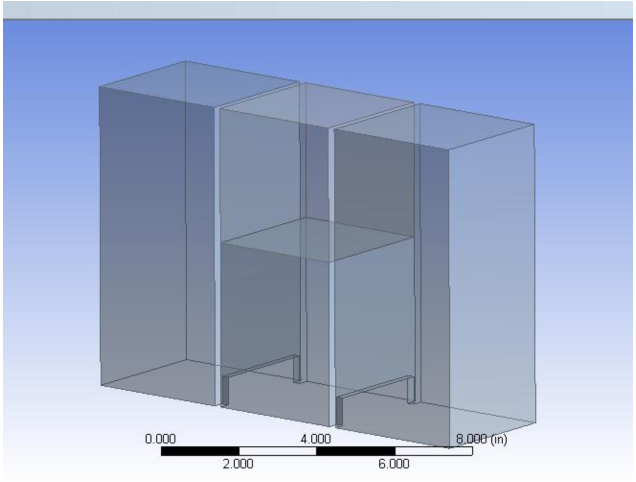



***Figure 11: Geometry import in Fluent***

**Step 2: Meshing**

Then meshing is done

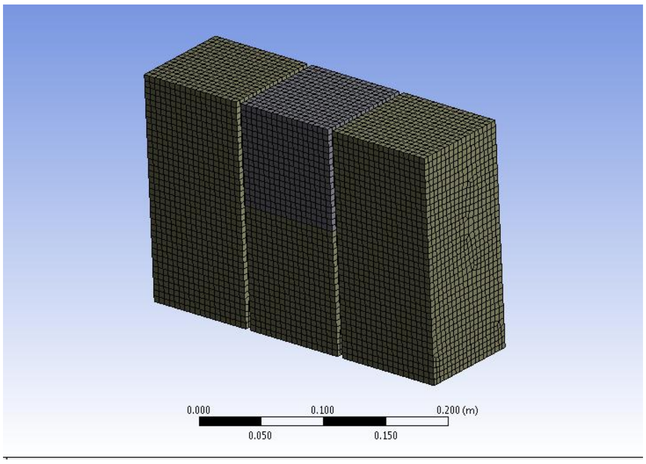



***Figure 12: Mesh Generation***

## Step 3: Setup

Fluent Launcher

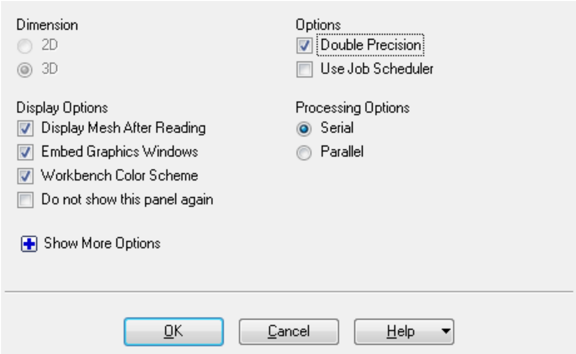



***Figure 13: Fluent Launcher***

General

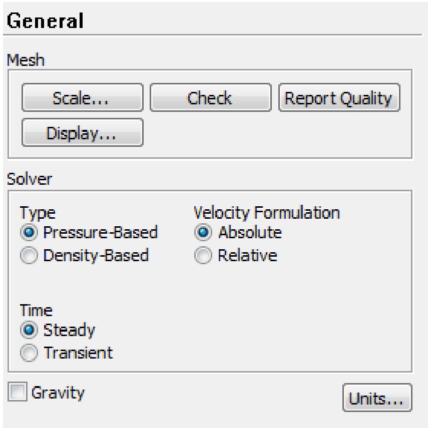



***Figure 14: General***

Models

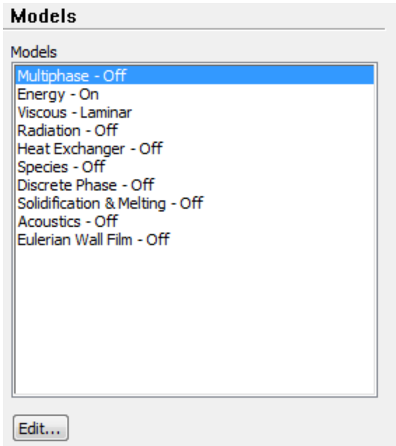



***Figure 15: Models***

Materials

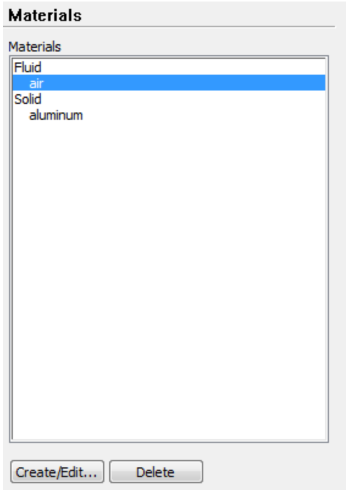



*Figure 16: Materials selection*

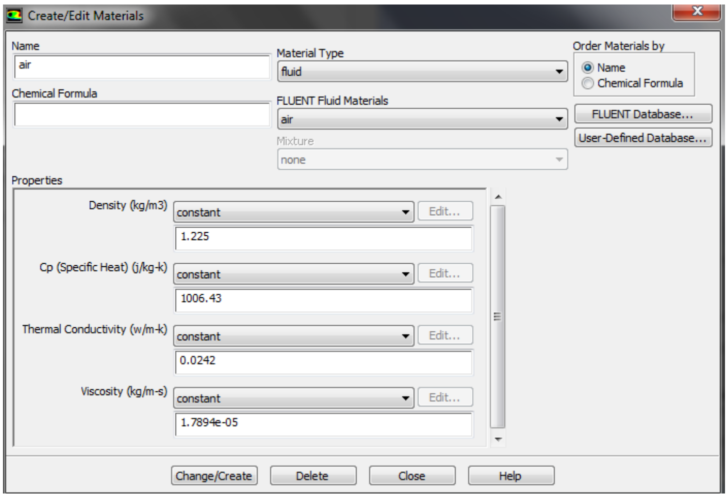



*Figure 17: Air Properties*

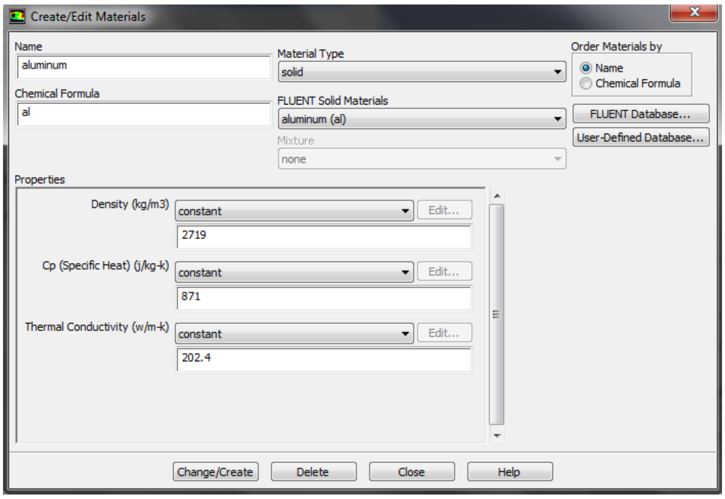



*Figure 18: Aluminium Properties*

Boundary Conditions

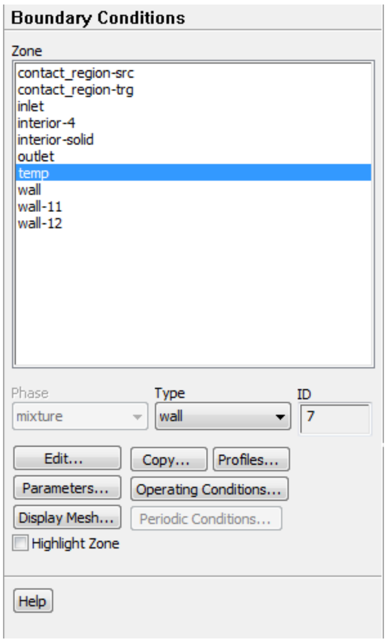



***Figure 19: Boundary Conditions***

Inlet Boundary conditions

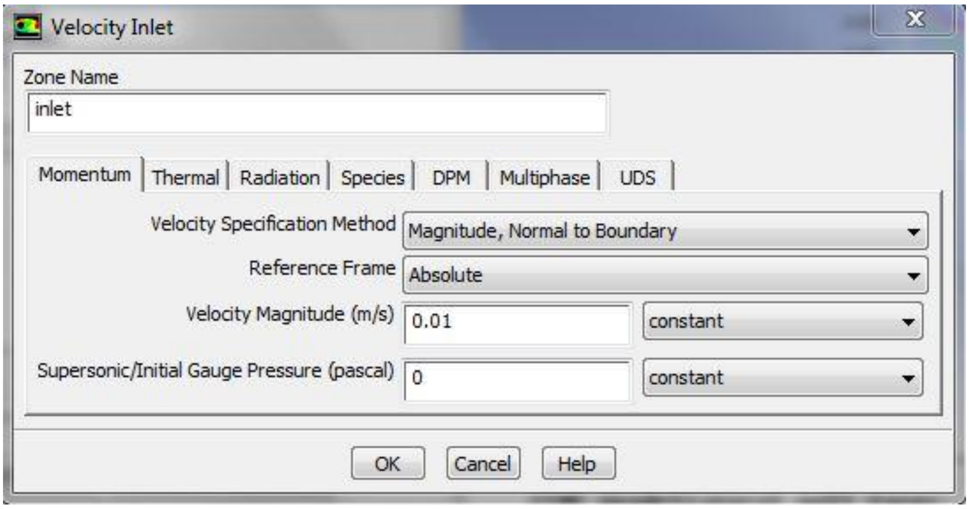



***Figure 20: Inlet Boundary Conditions (Momentum)***

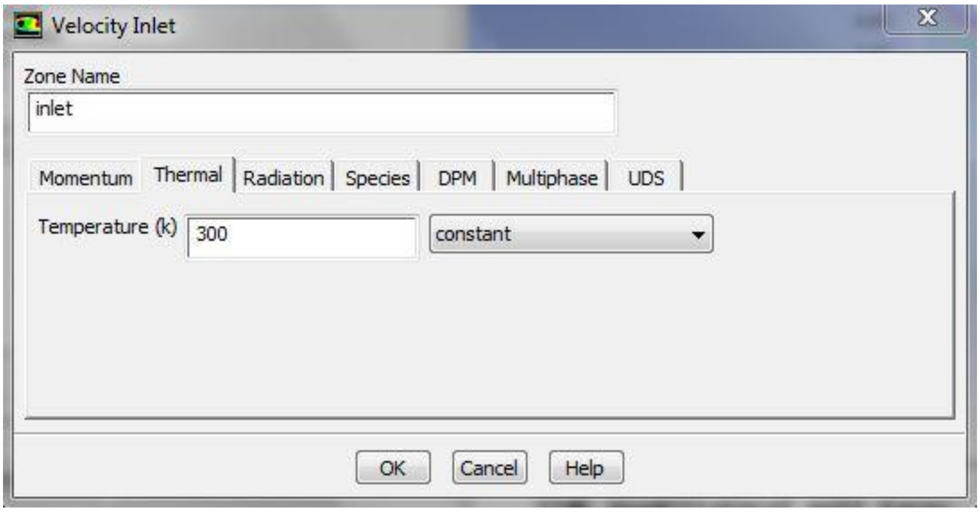



***Figure 21: Inlet Boundary Conditions (Thermal)***

Outlet Boundary conditions

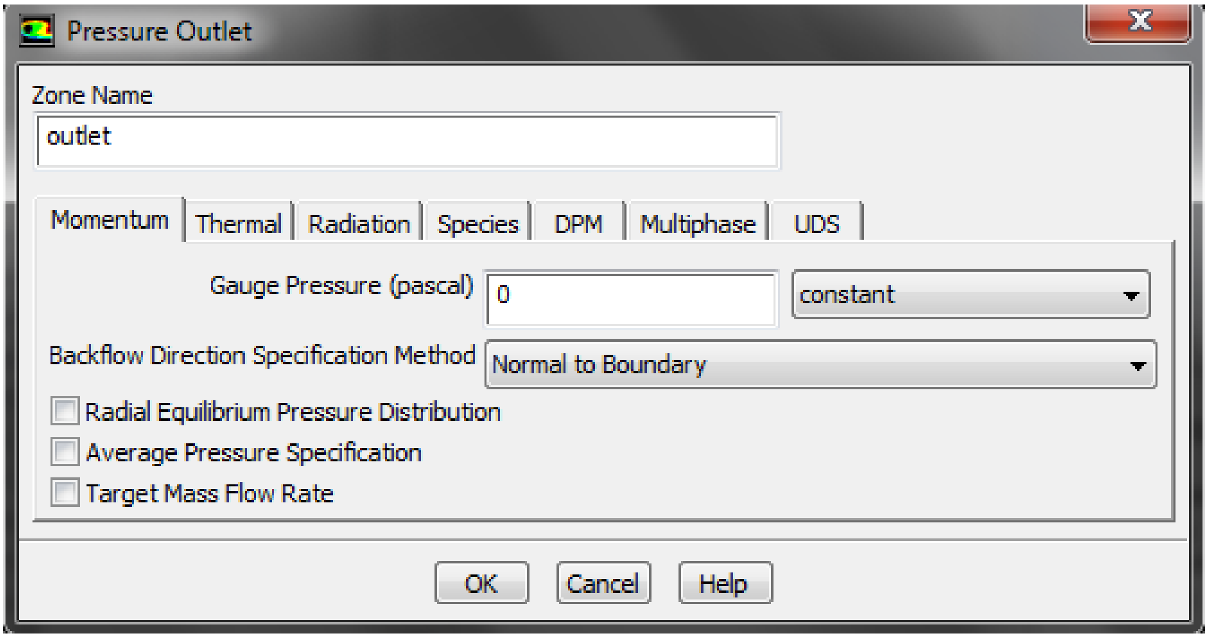



***Figure 22: Inlet Boundary Conditions (Momentum)***

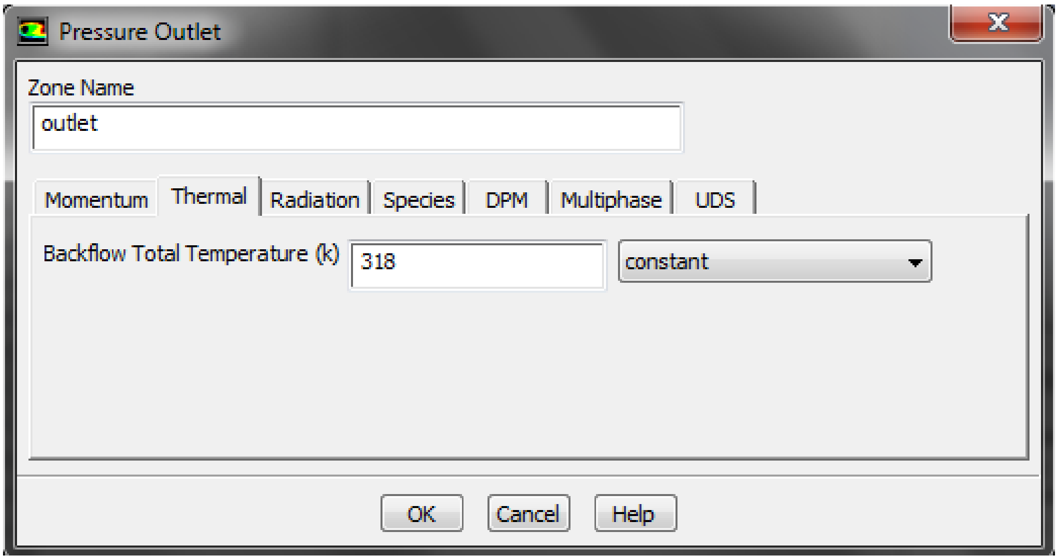



*Figure 23: Inlet Boundary Conditions (Thermal)*

Wall Boundary conditions

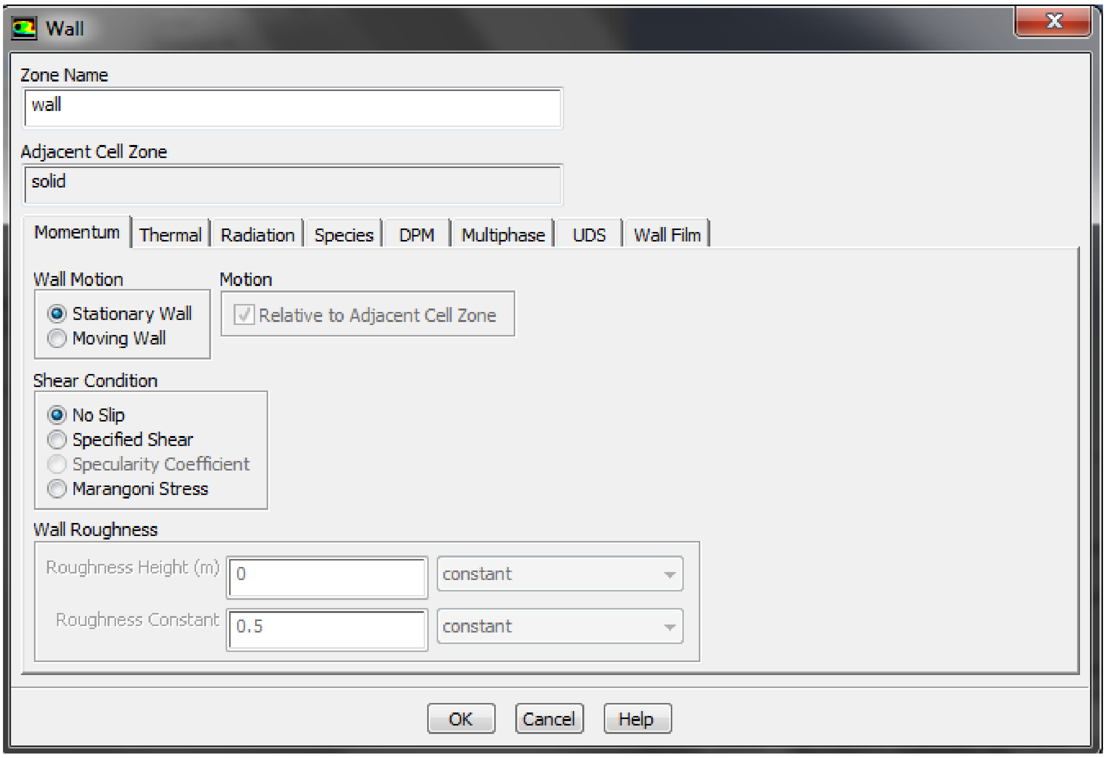



*Figure 24: Wall Boundary Conditions*

Peltier device boundary conditions

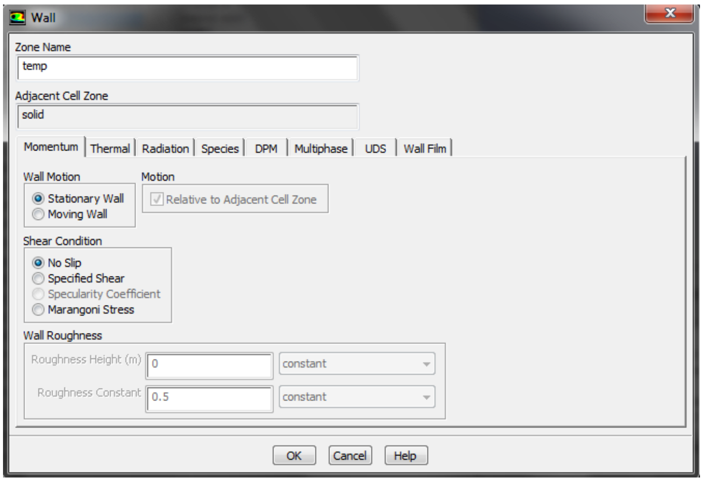



*Figure 25: Peltier Boundary Conditions (Momentum)*

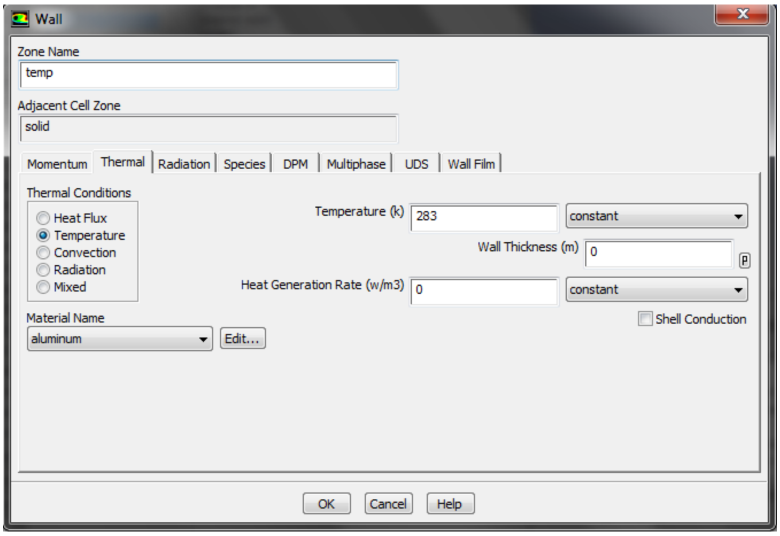



*Figure 26: Peltier Boundary Conditions (Thermal)*

Reference Values

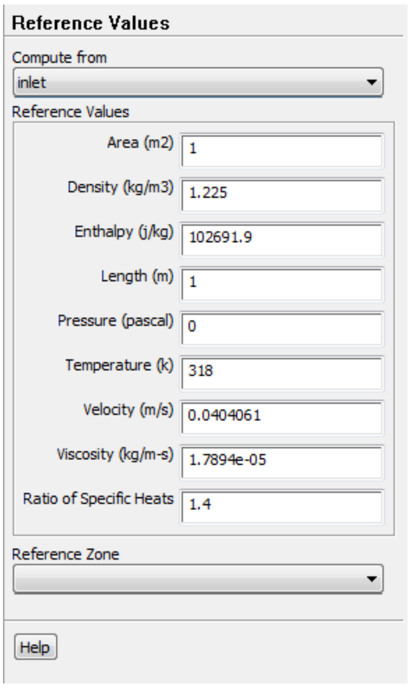



***Figure 27: Reference Values***

Solution Methods

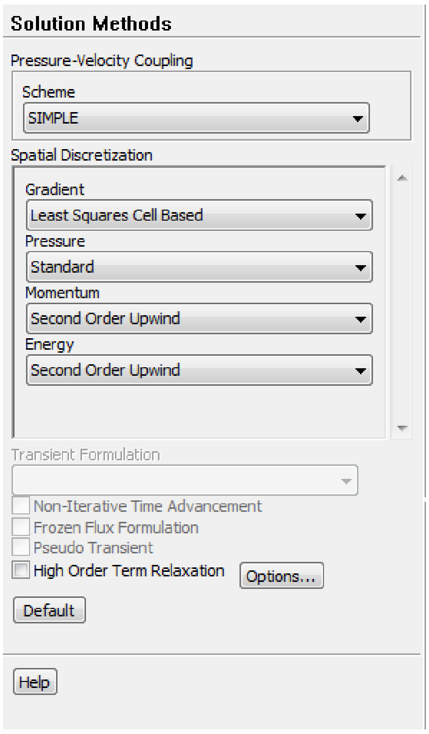



***Figure 28: Solution Methods***

Solution Initialisation

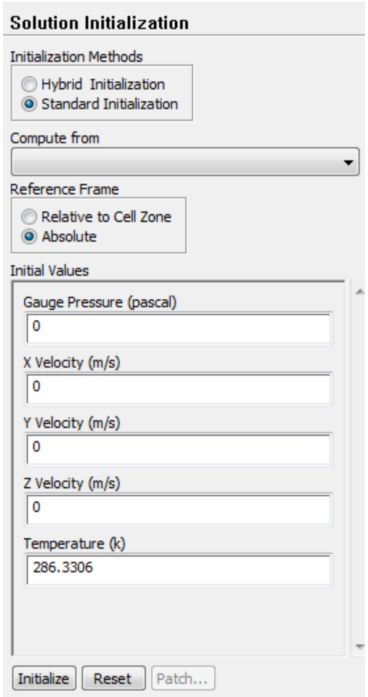



***Figure 29: Solution Initialisation***

Run Calculation

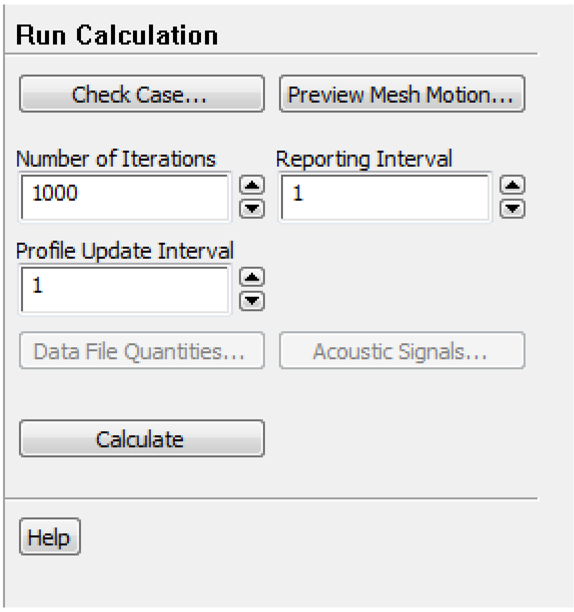



***Figure 30: Run Calculation***

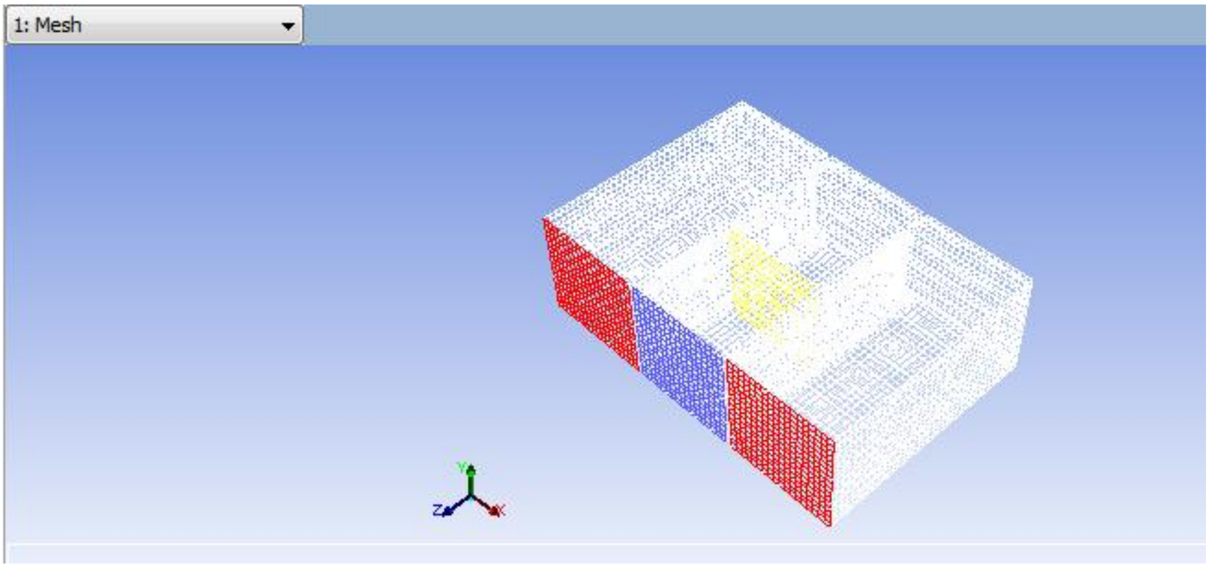



***Figure 31: Final Mesh***

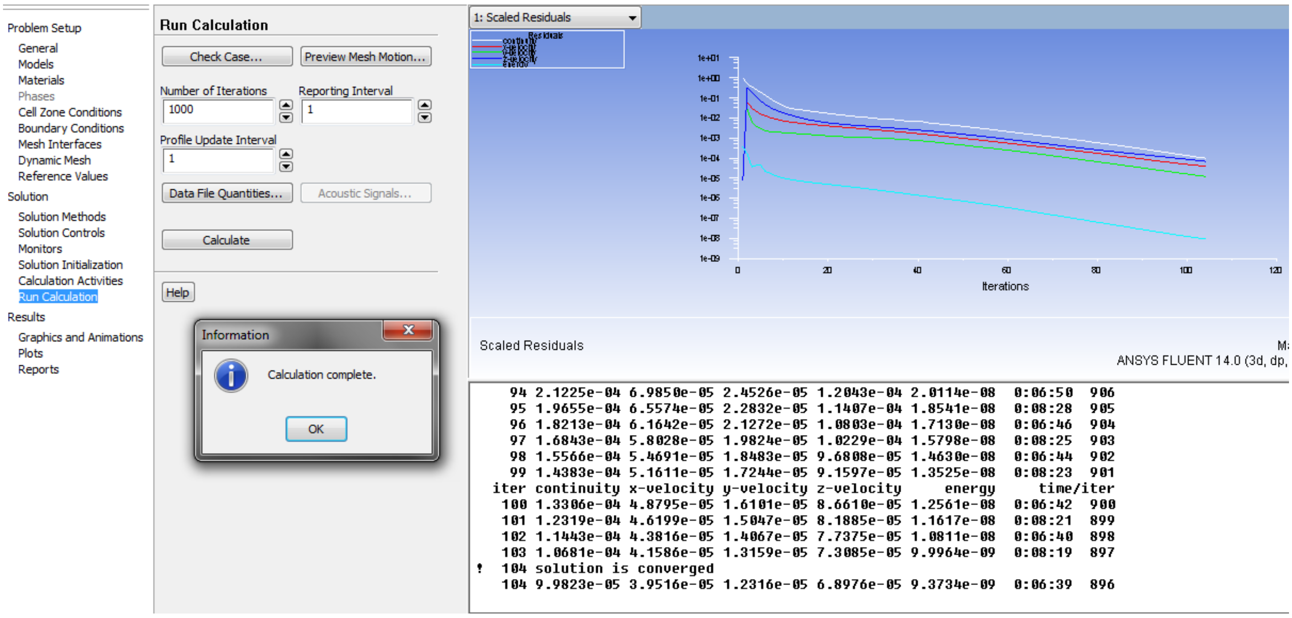
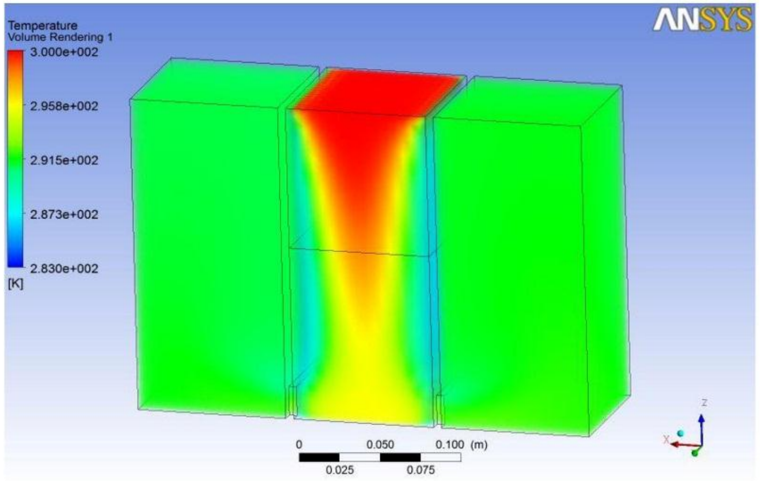



***Figure 32: Solution Convergence***

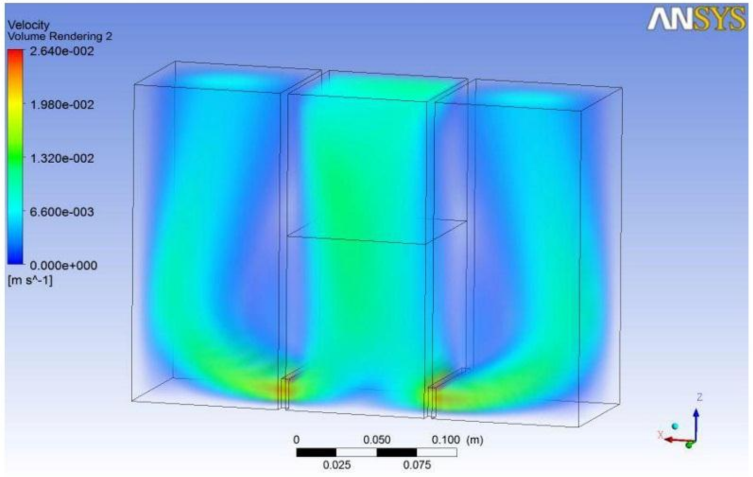
### Step 4: Results

After the solution is converged the temperature and velocity profiles for various inlet and temperature conditions are plotted. The profiles are plotted for the mid plane and also for the total body. The results are displayed below:

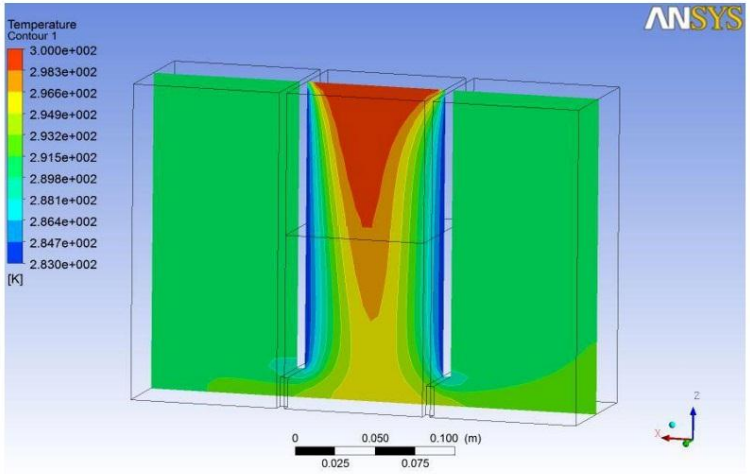
## Inlet Temp. 27°C



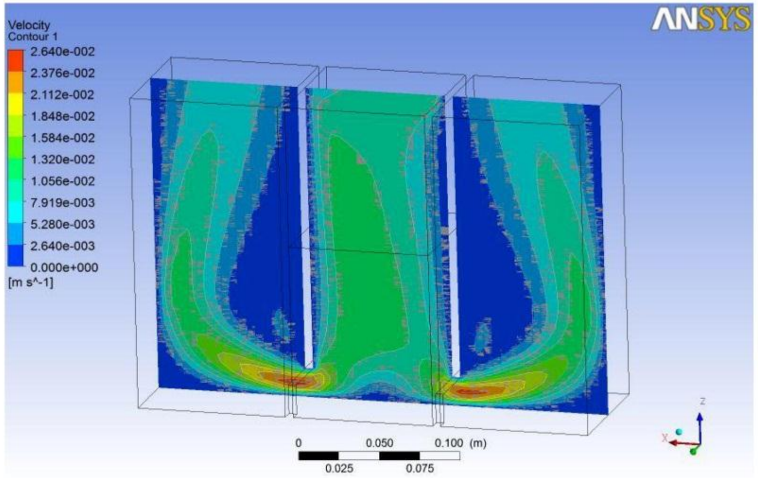

Temp. Profile (Body rendering)




Velocity Profile (Body rendering)



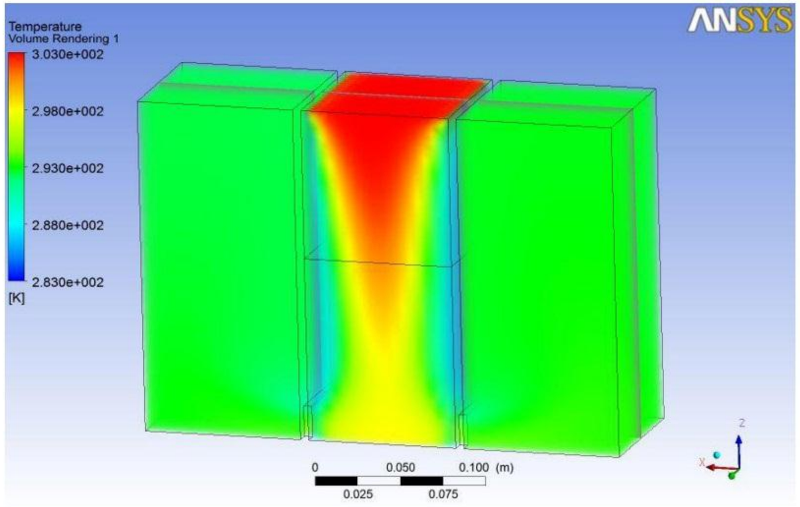

Temp. Profile (mid-plane)



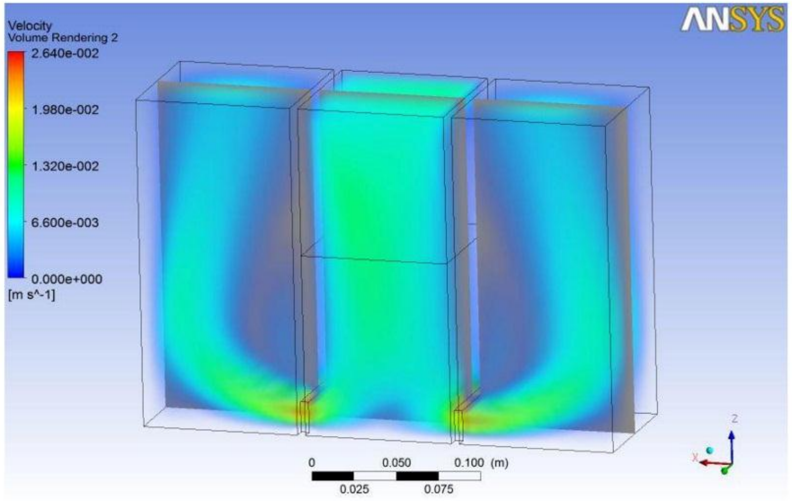

Velocity Profile (mid-plane)

*Figure 33: ANSYS results for inlet temperature 27$^0$C*

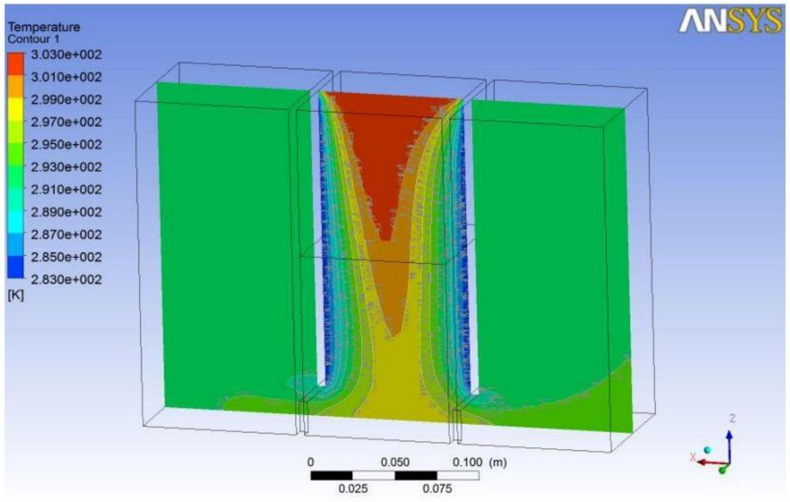
**Inlet Temp. 30°C**



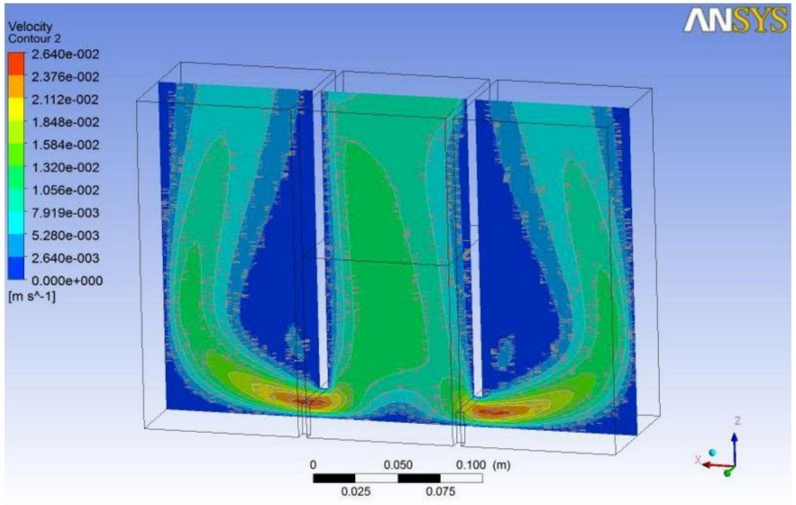

Temp. Profile (Body rendering)




Velocity Profile (Body rendering)



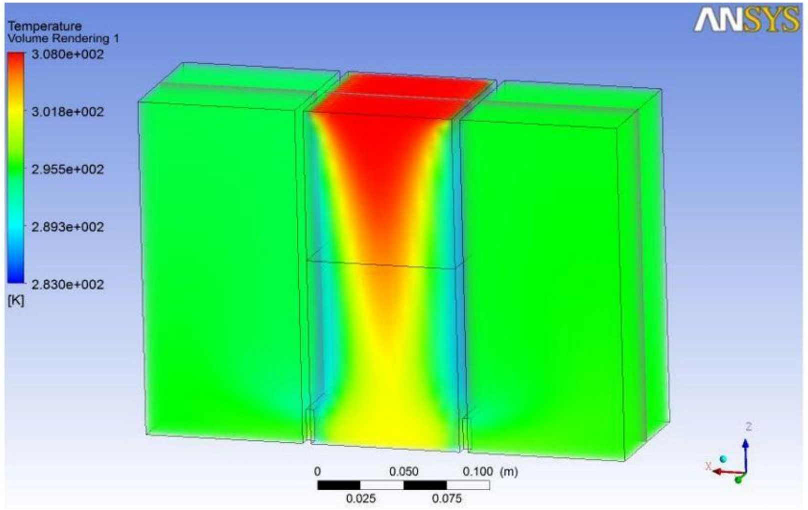

Temp. Profile (mid-plane)



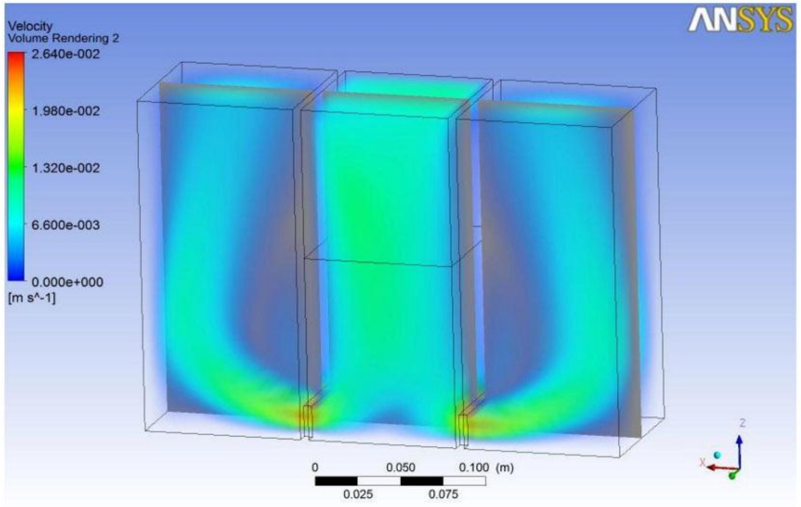

Velocity Profile (mid-plane)

***Figure 34: ANSYS results for inlet temperature 30$^0$C***

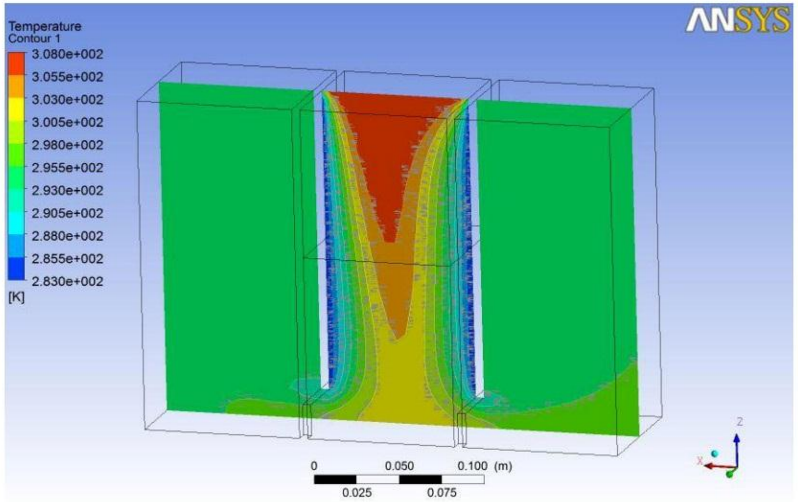
**Inlet Temp. 35°C**



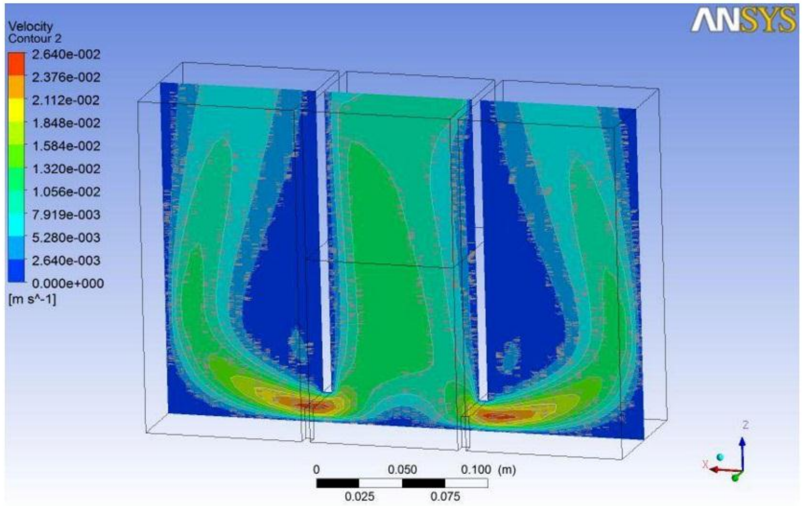

Temp. Profile (Body rendering)




Velocity Profile (Body rendering)



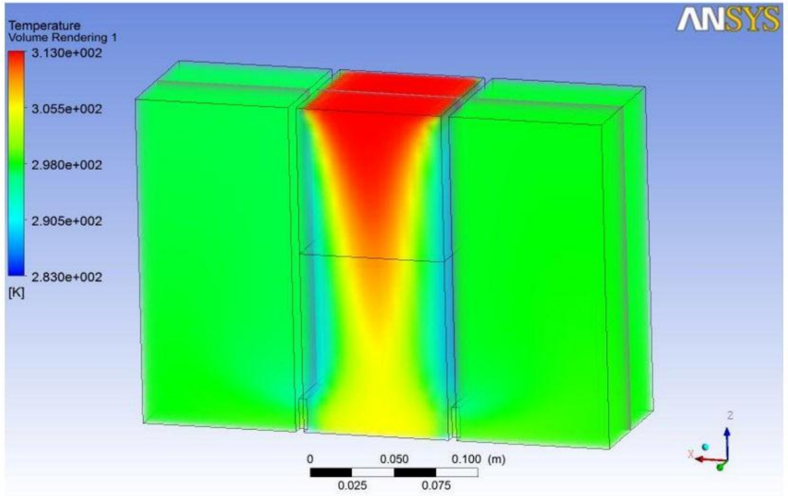

Temp. Profile (mid-plane)



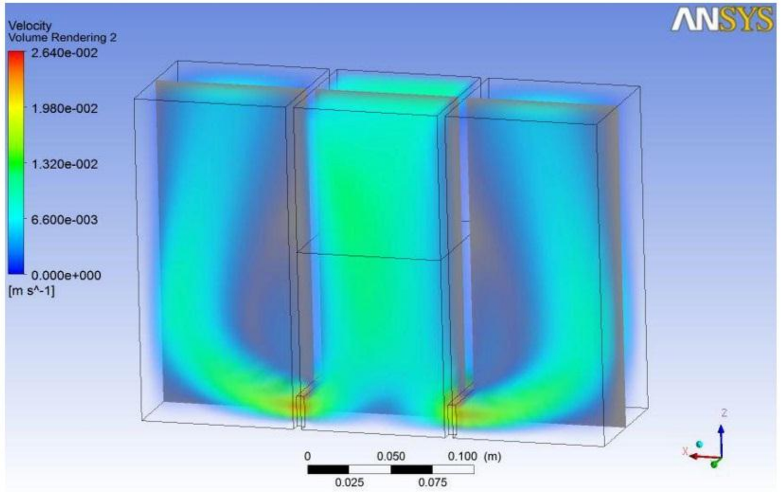

Velocity Profile (mid-plane)

***Figure 35: ANSYS results for inlet temperature 35$^0$C***

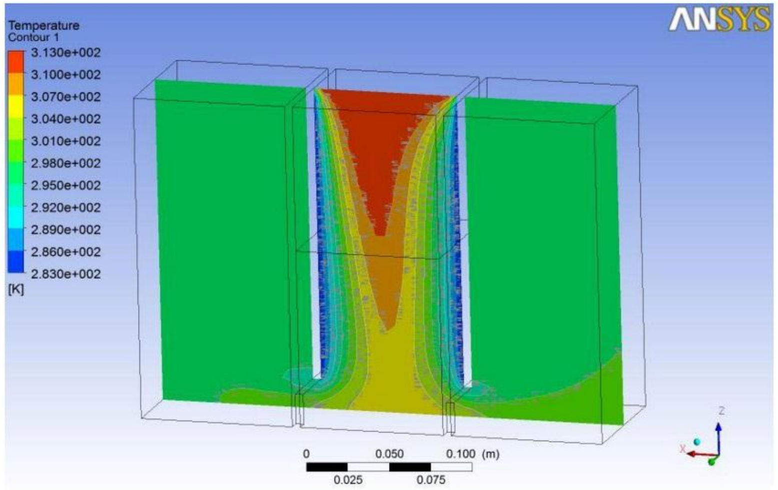
## Inlet Temp. 40°C



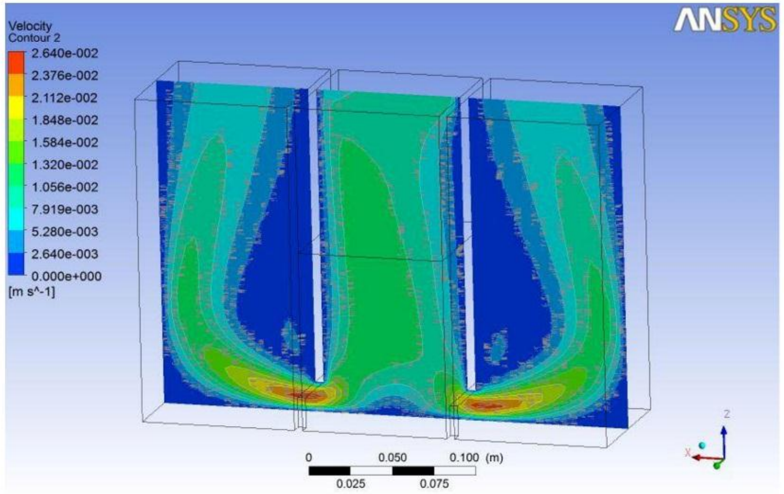

Temp. Profile (Body rendering)




Velocity Profile (Body rendering)



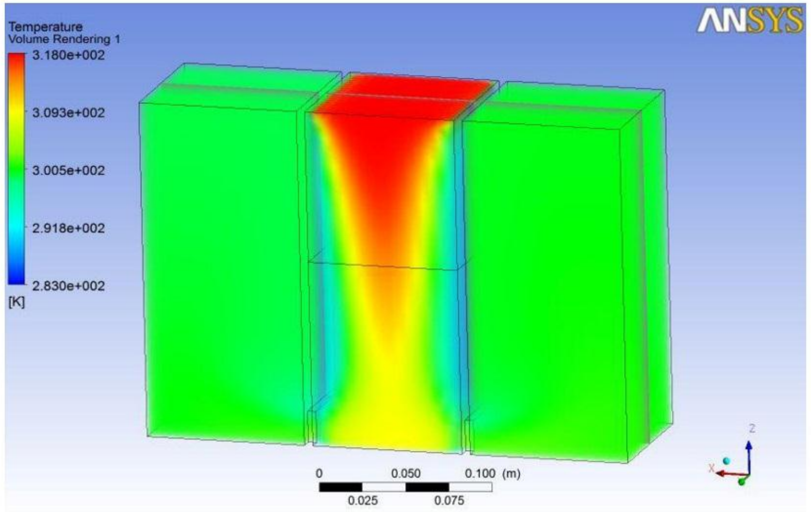

Temp. Profile (mid-plane)



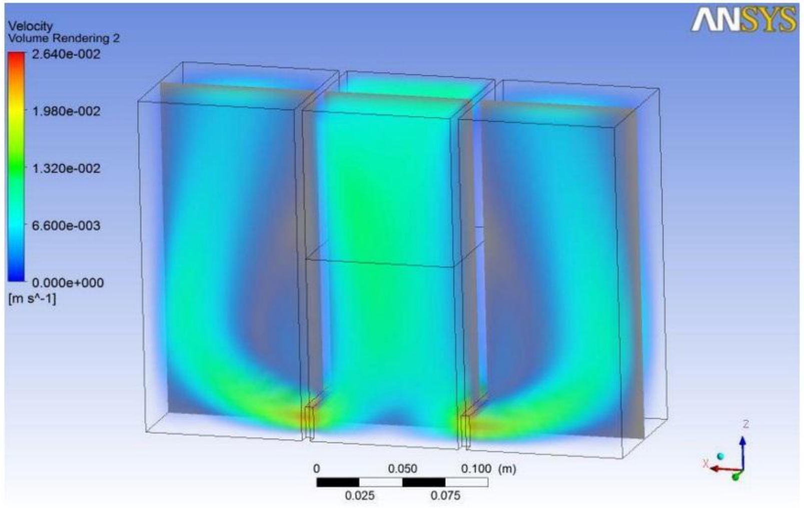

Velocity Profile (mid-plane)

***Figure 36: ANSYS results for inlet temperature 40$^0$C***

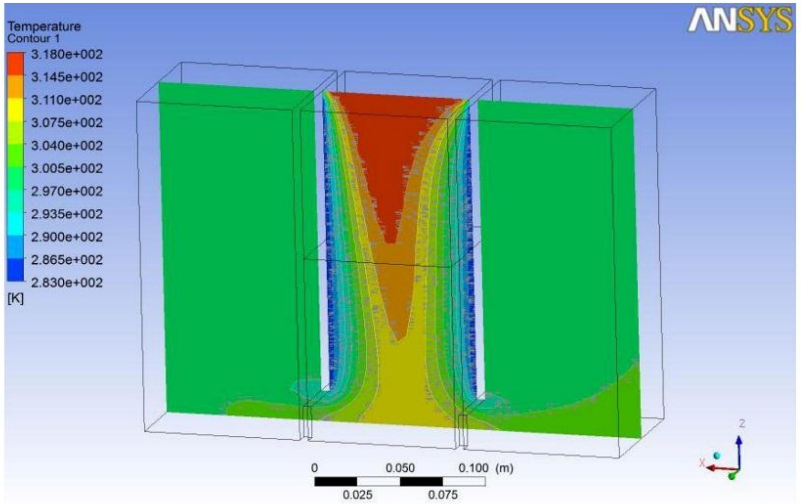
## Inlet Temp. 45°C



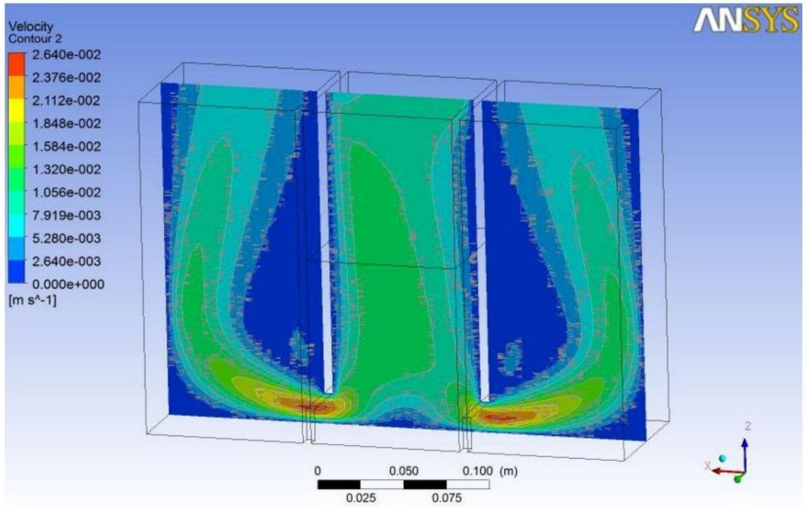

Temp. Profile (Body rendering)




Velocity Profile (Body rendering)




Temp. Profile (mid-plane)




Velocity Profile (mid-plane)

***Figure 37: ANSYS results for inlet temperature 45$^0$C***

# *Chapter-6*

# Discussion of calculations and results

After carrying out various calculations the results obtained are tallied and analysed. Earlier we had calculated the dew point temperatures required for different atmospheric conditions. Tables 1, 2, 3 and 4 shows the results obtained. Then we calculated the least temperatures that can be obtained from our device by specifying the boundary conditions in FLUENT workbench. The results of the analysis are shown in figures 33,34,35,36 and 37. Both these results are then tallied. The conclusions are:

1. For inlet air temperature $30^0$C figure 34 shows that the temperature of air in the device drops down to that of 293 K or $20^0$C. Table 1 shows that for temperature $30^0$C the dew point temperature is greater than $20^0$C for relative humidity 60% or higher. Thus it is clear that if atmospheric temperature is $30^0$C and relative humidity is greater than 60% then the device will start condensing water.
2. For inlet air temperature $35^0$C figure 35 shows that the temperature of air in the device drops down to that of 295.5 K or $22.5^0$C. Table 2 shows that for temperature $35^0$C the dew point temperature is greater than $22.5^0$C for relative humidity 50% or higher. Thus it is clear that if atmospheric temperature is $35^0$C and relative humidity is greater than 50% then the device will start condensing water.
3. For inlet air temperature $40^0$C figure 36 shows that the temperature of air in the device drops down to that of 298 K or $25^0$C. Table 3 shows that for temperature $40^0$C the dew point temperature is greater than $25^0$C for relative humidity 45% or higher. Thus it is clear that if atmospheric temperature is $40^0$C and relative humidity is greater than 45% then the device will start condensing water.
4. For inlet air temperature $45^0$C figure 37 shows that the temperature of air in the device drops down to that of 300.5 K or $27.5^0$C. Table 4 shows that for temperature $45^0$C the dew point temperature is greater than $27.5^0$C for relative humidity 45% or higher. Thus it is clear that if atmospheric temperature is $45^0$C and relative humidity is greater than 45% then the device will start condensing water.

From all the above inferences we can finally conclude that if ambient temperature is $35^0$C or higher and if relative humidity is greater than 50% then the device will function well and it will start condensing water. Thus in order to find if the device will work in the coastal areas of India metrological data are collected from internet for major coastal cities of India and the data are presented below.

## PURI

Monthly Averaged Relative Humidity (%)

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | 49.68 | 68.94 | 60.61 | 77.98 | 78.51 | 84.37 | 82.50 | 81.86 | 81.07 | 74.19 | 54.16 | 43.30 | 69.72 |
| 2001 | 51.05 | 63.10 | 77.95 | 75.83 | 83.77 | 82.68 | 84.44 | 84.83 | 83.07 | 82.07 | 73.22 | 50.51 | 74.42 |
| 2002 | 66.46 | 61.62 | 71.27 | 80.11 | 81.51 | 85.15 | 81.70 | 82.57 | 82.60 | 77.50 | 62.43 | 50.69 | 73.69 |
| 2003 | 56.90 | 78.35 | 73.71 | 80.10 | 83.21 | 85.38 | 86.83 | 86.10 | 84.06 | 85.04 | 63.00 | 58.15 | 76.71 |
| 2004 | 61.36 | 56.73 | 65.13 | 84.47 | 79.58 | 80.45 | 83.62 | 78.44 | 83.90 | 77.71 | 51.21 | 53.88 | 71.41 |
| 2005 | 59.60 | 63.01 | 68.76 | 72.45 | 78.20 | 79.64 | 83.71 | 80.09 | 84.06 | 83.55 | 56.93 | 53.81 | 72.04 |
| 2000 - 2005 | 57.51 | 65.29 | 69.57 | 78.49 | 80.80 | 82.95 | 83.80 | 82.31 | 83.12 | 80.01 | 60.16 | 51.72 | 72.98 |
| Min Dif | -7.83 | -8.56 | -8.96 | -6.04 | -2.60 | -3.30 | -2.10 | -3.88 | -2.05 | -5.82 | -8.95 | -8.43 | -5.71 |
| Max Dif | 8.95 | 13.05 | 8.37 | 5.98 | 2.98 | 2.44 | 3.03 | 3.79 | 0.93 | 5.03 | 13.06 | 6.43 | 6.17 |

## Vishakhapatnam

Monthly Averaged Relative Humidity (%)

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | 59.21 | 73.24 | 68.36 | 81.06 | 77.63 | 81.70 | 79.73 | 81.00 | 80.36 | 70.65 | 56.02 | 46.81 | 71.27 |
| 2001 | 56.58 | 69.63 | 73.19 | 80.43 | 81.97 | 79.48 | 80.90 | 80.20 | 83.78 | 78.91 | 69.55 | 55.01 | 74.13 |
| 2002 | 69.57 | 68.23 | 71.03 | 79.63 | 80.78 | 82.59 | 77.99 | 78.40 | 77.50 | 77.57 | 62.52 | 56.08 | 73.51 |
| 2003 | 64.01 | 78.39 | 76.47 | 77.22 | 77.98 | 82.61 | 84.46 | 81.89 | 82.35 | 82.12 | 61.27 | 63.42 | 76.00 |
| 2004 | 67.06 | 62.93 | 71.19 | 84.75 | 83.00 | 79.98 | 82.26 | 75.08 | 82.22 | 77.92 | 61.42 | 57.23 | 73.77 |
| 2005 | 66.80 | 70.83 | 72.68 | 80.15 | 84.78 | 82.45 | 81.09 | 77.86 | 82.88 | 84.84 | 61.03 | 61.55 | 75.60 |
| 2000 - 2005 | 63.87 | 70.54 | 72.15 | 80.54 | 81.02 | 81.47 | 81.07 | 79.07 | 81.51 | 78.67 | 61.97 | 56.68 | 74.05 |
| Min Dif | -7.29 | -7.61 | -3.80 | -3.32 | -3.39 | -1.99 | -3.08 | -4.00 | -4.02 | -8.01 | -5.95 | -9.87 | -5.19 |
| Max Dif | 5.70 | 7.85 | 4.32 | 4.21 | 3.76 | 1.14 | 3.39 | 2.82 | 2.27 | 6.17 | 7.58 | 6.74 | 4.66 |

***Figure 38: Metrological data showing monthly average relative humidity data for Puri and Vishakhapatnam* [11]**

**Mumbai**

**Monthly Averaged Relative Humidity (%)**

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | 57.28 | 59.72 | 67.23 | 77.99 | 76.51 | 80.69 | 81.00 | 80.83 | 78.30 | 75.89 | 56.42 | 56.83 | 70.76 |
| 2001 | 61.43 | 69.19 | 72.98 | 70.09 | 79.36 | 80.28 | 80.25 | 80.77 | 79.74 | 70.97 | 53.86 | 56.72 | 71.32 |
| 2002 | 54.21 | 67.96 | 69.83 | 73.79 | 79.82 | 79.88 | 79.31 | 78.76 | 75.44 | 71.31 | 59.96 | 60.77 | 70.93 |
| 2003 | 66.20 | 75.84 | 70.40 | 77.51 | 76.43 | 81.42 | 81.20 | 81.53 | 80.16 | 72.65 | 62.38 | 59.32 | 73.72 |
| 2004 | 57.51 | 69.49 | 69.34 | 74.63 | 73.64 | 77.55 | 78.99 | 80.08 | 76.80 | 64.89 | 61.01 | 53.10 | 69.72 |
| 2005 | 53.33 | 64.33 | 76.40 | 68.14 | 72.67 | 76.64 | 80.63 | 79.71 | 79.16 | 71.04 | 57.18 | 50.60 | 69.18 |
| 2000 - 2005 | 58.33 | 67.76 | 71.03 | 73.69 | 76.41 | 79.41 | 80.23 | 80.28 | 78.27 | 71.12 | 58.47 | 56.22 | 70.93 |
| Min Dif | -5.00 | -8.04 | -3.80 | -5.56 | -3.73 | -2.77 | -1.24 | -1.52 | -2.83 | -6.24 | -4.61 | -5.63 | -4.25 |
| Max Dif | 7.87 | 8.09 | 5.37 | 4.30 | 3.42 | 2.01 | 0.97 | 1.25 | 1.89 | 4.77 | 3.91 | 4.55 | 4.03 |

**Kanyakumari**

**Monthly Averaged Relative Humidity (%)**

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | 68.28 | 70.48 | 70.50 | 82.31 | 81.94 | 80.39 | 77.51 | 81.37 | 82.59 | 81.41 | 72.06 | 65.04 | 76.15 |
| 2001 | 67.37 | 72.49 | 73.22 | 85.64 | 83.84 | 80.90 | 82.74 | 81.69 | 77.48 | 84.32 | 80.15 | 73.93 | 78.67 |
| 2002 | 67.81 | 66.84 | 70.21 | 85.57 | 83.87 | 81.42 | 80.60 | 83.03 | 75.42 | 83.33 | 84.33 | 72.90 | 77.99 |
| 2003 | 65.08 | 73.20 | 74.17 | 84.11 | 83.42 | 83.64 | 82.80 | 82.41 | 81.99 | 81.68 | 80.93 | 70.04 | 78.62 |
| 2004 | 67.02 | 61.50 | 70.24 | 84.56 | 80.26 | 79.96 | 81.26 | 77.64 | 80.71 | 83.53 | 79.24 | 68.18 | 76.20 |
| 2005 | 68.77 | 64.88 | 75.28 | 82.49 | 82.32 | 80.06 | 82.45 | 71.65 | 78.89 | 81.08 | 81.79 | 78.31 | 77.40 |
| 2000 - 2005 | 67.39 | 68.23 | 72.27 | 84.11 | 82.61 | 81.06 | 81.23 | 79.63 | 79.51 | 82.56 | 79.75 | 71.40 | 77.48 |
| Min Dif | -2.31 | -6.73 | -2.06 | -1.80 | -2.35 | -1.10 | -3.72 | -7.98 | -4.09 | -1.48 | -7.69 | -6.36 | -3.97 |
| Max Dif | 1.39 | 4.96 | 3.01 | 1.52 | 1.26 | 2.58 | 1.57 | 3.39 | 3.08 | 1.76 | 4.58 | 6.91 | 3.00 |

***Figure 38: Metrological data showing monthly average relative humidity data for Mumbai and Kanyakumari* [11]**

From the above metrological data it is clear that the relative humidity of coastal cities in India remains above 50% throughout the year. Hence the developed device will work round the year without any problems.

# *Chapter-7*

# Fabricated Prototype Model

Based on the CAD model a prototype was built. The outer casing of the prototype is made up of acrylic sheet which is light and cheap material and easy to work with. Two Peltier devices (TEC-12706) are fitted as shown in figure 10. The draft fans for cooling the Peltier device were attached directly to the heat sink of the Peltier device in order to increase the efficiency of cooling which is a slight variation from the actual CAD model. An inlet draft fan was also attached at the top of the device which will draw the humid atmospheric air for condensation.

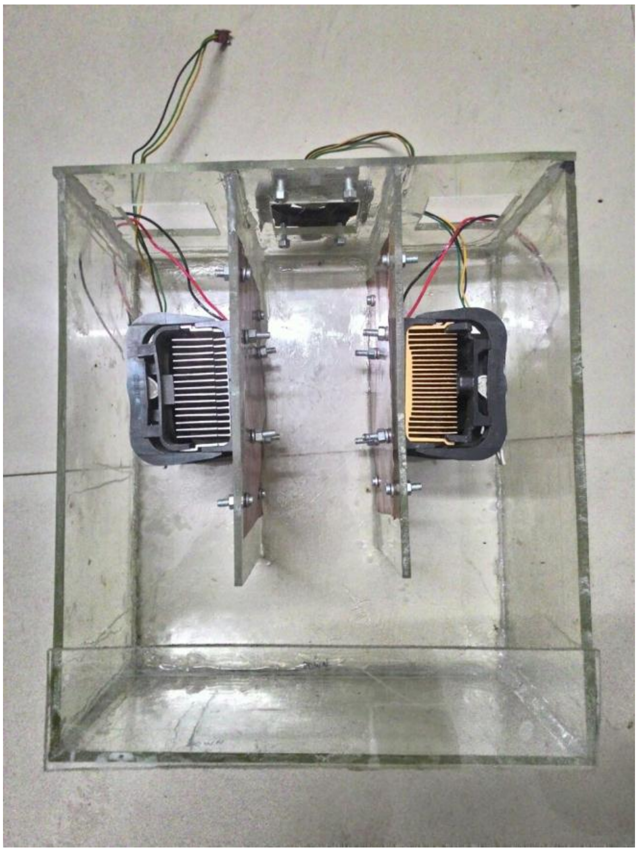


***Figure 40: Prototype***

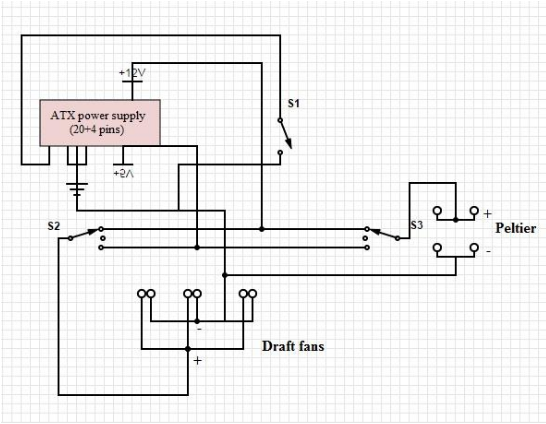



*Figure 41: Circuit diagram*

*Figure 42: Front view of electrical circuit*

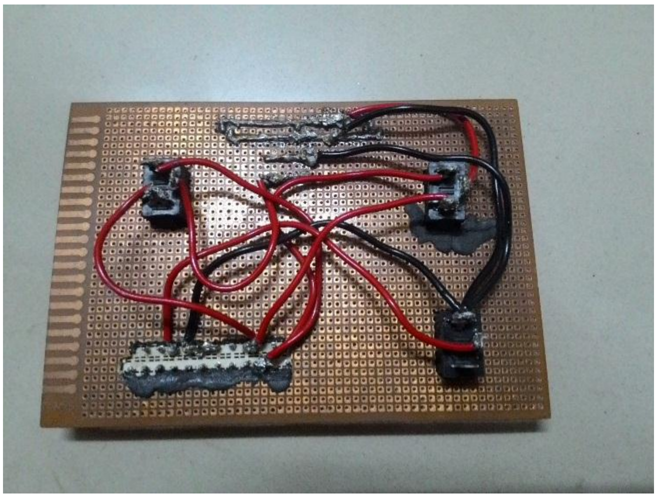


*Figure 43: Final connection*

# *Chapter-8*

# Conclusion and future scope

The prototype was subjected to tests at Rourkela and it was found that the water output from the device was not satisfactory. After diligent study and research we found that the following reasons may be responsible for the low water output of the device:

1. The tests were done in Rourkela which is a region with low humidity. And based on our calculation the humidity of a region must remain above 50% for proper functioning of the device. So we expect that the water output may increase if the device is tested in coastal areas where the humidity is high.
2. As such the cold surface area of the Peltier device is very less (4cm*4cm). So we used a copper plate in contact with the cooling surface of the Peltier device because of its high conductivity expecting that the cold surface area will increase thereby increasing the condensation area. But finally in the prototype when we used the copper plate proper thermal contact between the cold Peltier surface and the copper plate could not be achieved. This maybe the possible reason for low efficiency.
3. On running the device, initially condensation started and water droplets were formed on the cold surface of the Peltier device. But subsequently due to the deposition of these water droplets the thermal conductivity of the region decreased as water is not a good thermal conductor. Hence the condensation process slowed down subsequently.

   In order to increase the output in the future, a wiping mechanism may be incorporated in the device so as to increase the condensation rate.
4. Presently, we have used only two Peltier devices in the prototype. In the future the prototype may incorporate another two Peltier devices so as to increase the water output.
5. For giving the prototype an environmental friendly flavour it may include a solar power source (solar panel) in place of the present AC power source without much modifications in the circuitry.

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